BEACH EROSION CONTROL REPORT ON COOPERATIVE STUDY OF

FALMOUTH MASSACHUSETTS

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
HURRICANE PROTECTION UNIT
[illegible]
PROVIDENCE, RHODE ISLAND 02903

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS

WALTHAM, MASS.

DECEMBER 28, 1962

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

ADDRESS REPLY TO:
DIVISION ENGINEER

REFER TO FILE NO.

NEDGW

15 April 1963

REVISED PAGES AND ERRATA

BEACH EROSION CONTROL REPORT ON
COOPERATIVE STUDY OF FALMOUTH, MASSACHUSETTS

Attached are revised pages 27, 28, 29, 30, L-1, L-2, L-3, L-4, L-5, and L-6 comprising revisions of 15 April 1963 to the subject report dated 28 December 1962. Also included is an Errata Sheet pertaining to Plate No. 4 of the report. Original pages 27 through 30, and L-1 through L-7 should be removed from the subject report, and the revised pages substituted therefor. The error described by the Errata Sheet should be corrected on Plate No. 4.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
HURRICANE PROTECTION UNIT
209 FEDERAL BUILDING
PROVIDENCE, RHODE ISLAND 02903

ERRATA SHEET

15 April 1963

BEACH EROSION CONTROL REPORT ON COOPERATIVE STUDY OF FALMOUTH, MASSACHUSETTS

On Plate No. 4, Profile No. 8, the 6.6 foot sounding should be changed to read 16.6.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 Trapelo Road
Waltham 54, Mass.

NEDGW

11 January 1963

NOTICE OF BEACH EROSION CONTROL REPORT ON
COOPERATIVE STUDY OF FALMOUTH, MASSACHUSETTS

Notice is hereby given that the Beach Erosion Control Report on Cooperative Study of Falmouth, Massachusetts made to determine the best method of restoring and stabilizing beaches and stabilizing the bluff areas, prosecuted jointly by the Commonwealth of Massachusetts and the United States under the provisions of Section 2 of the River and Harbor Act, approved 3 July 1930, as amended and supplemented, has been made by the Division Engineer. The report is unfavorable to Federal participation in the cost of construction of protective works. Due to the adequacy of public beach areas for recreational use, the limited value of benefits to be derived from protecting public property and the private ownership and the consequent private nature of benefits to be derived from protecting private property, the public interest as required by Public Law 826, 84th Congress is insufficient to warrant Federal participation in the cost of construction of the plans of protection which have been considered. It has therefore been recommended that no project be adopted by the United States at this time for the protection or improvement of the shores of Falmouth, Massachusetts.

Plans of protection and improvements shown on the inclosed plates, have been developed for shore areas for consideration by local interests as follows:

a. Between Nobska Point and Falmouth Beach. - Construct stone mounds or stone revetment wherever needed for bluff protection. Estimated cost of construction $81.00 per linear foot.

b. Between Falmouth Inner Harbor and Bluffs at Falmouth Heights. - Widen 1,000 feet of beach by direct placement of sand fill, lengthen Falmouth Harbor East Jetty to a 250-foot length, enlarge and lengthen the existing groin to a 250-foot length. Estimated total cost $89,000.

c. Falmouth Heights Bluffs. - Place additional riprap revetment along the toe of approximately 1,450 feet of wall, place stone revetment on approximately 750 feet of slope above the wall and control surface runoff wherever needed. Estimated total cost $48,000.

d. Mara Vista. - Construct low walls, approximately 1,900 feet long along the seaward side of the shore road. Estimated total cost $28,000.

e. Acapesket. - Widen 1,300 feet of beach by direct placement of sand fill, enlarge and lengthen four (4) existing groins to 345 to 510-foot lengths. Estimated total cost $278,000.

f. Davisville. - Widen 1,500 feet of beach by direct placement of sand fill, construct a jetty 530 feet long and two groins 340 and 510 feet long. Estimated total cost $207,000.

g. Menauhant. - Widen 1,600 feet of beach by direct placement of sand fill, enlarge and lengthen three (3) existing groins to 240 to 280-foot lengths. Estimated total cost $195,000.

In addition, general methods of protection and improvement were considered for other areas which did not require development of detailed plans.

In accordance with law, the report is being referred for review to the Beach Erosion Board in Washington, D. C. Interested parties may present written views on the report to the Board. Statements submitted should not repeat material previously presented to the Division Engineer, or contained in his report, as this information is already available to the Board. Information submitted should be new, specific in nature and bear directly on the findings in the Report.

Hearings will be held only on written request explaining the need to present material not included in the report.

Written communications are to be mailed to the Beach Erosion Board, Washington 16, D. C., in time to reach the Board by 12 February 1963. If extension of this date is considered necessary, requests giving reasons and additional time desired should be submitted as soon as possible.

The Board considers communications and the Report at a date subsequent to expiration of this notice. Information furnished by mail receives the same attention as that received at a public hearing. Should the Board not be convinced of the soundness of the recommendations in the Report, notice to that effect will be mailed to all known interested parties prior to final action.

Further information may be obtained from this office at 424 Trapelo Road, Waltham 54, Massachusetts. Interested parties, including the press, may make such notes of the contents of the report as they desire. However, copies of the report will not be loaned for use outside of the office, but interested parties may purchase copies of the report, or parts thereof, including illustrations, at the cost of reproduction of $3.00 from the Division Engineer, U. S. Army Engineer Division, New England, 424 Trapelo Road, Waltham 54, Massachusetts. Checks and money orders should be made payable to the Treasurer of the United States.

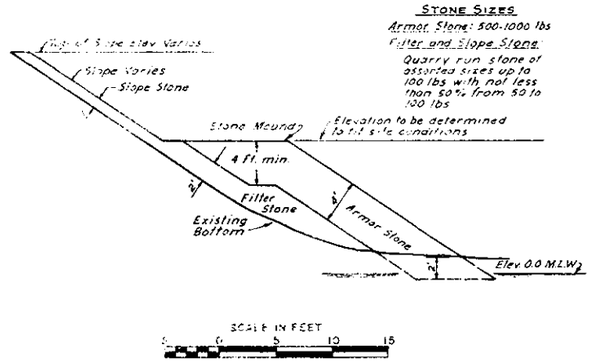
You are requested to give the foregoing information to any persons known by you to be interested in the report, and who, not being known by the Division Engineer, do not receive a copy of this public notice.

Incl
2 Plates

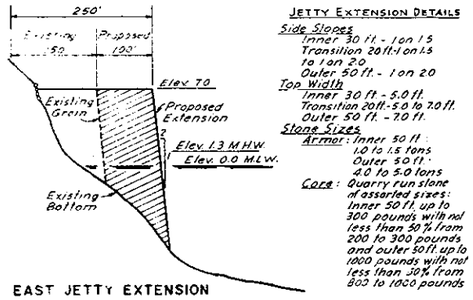
P. C. HYZER
Colonel, Corps of Engineers
Division Engineer

CORPS OF ENGINEERS

U. S. ARMY



TYPICAL SECTION OF PROPOSED STONE PROTECTION FOR BLUFFS EAST OF NOBSKA POINT



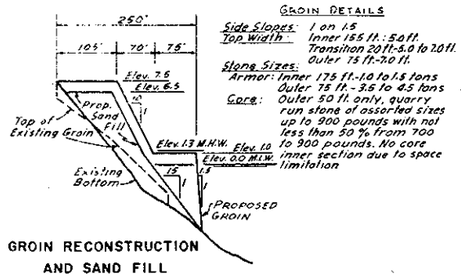
EAST JETTY EXTENSION

JETTY EXTENSION DETAILS

Side Slopes
Inner 30 ft - 1 on 1.5
Transition 20 ft-1 on 1.5 to 1 on 2.0
Outer 50 ft. - 1 on 2.0

Top Width
Inner 30 ft - 5.0 ft.
Transition 20 ft - 5.0 to 7.0 ft.
Outer 50 ft. - 7.0 ft.

Stone Sizes
Armor: Inner 50 ft 1.0 to 1.5 tons
Outer 50 ft 4.0 to 5.0 tons
Core: Quarry run stone of assorted sizes: Inner 50 ft. up to 300 pounds with not less than 50% from 200 to 300 pounds and outer 50 ft. up to 1000 pounds with not less than 30% from 800 to 1000 pounds



GROIN RECONSTRUCTION AND SAND FILL

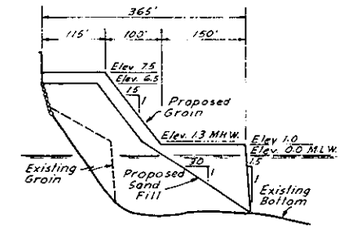
GROIN DETAILS

Side Slopes: 1 on 1.5
Top Width: Inner 155 ft.: 5.0 ft. Transition 20 ft-5.0 to 7.0 ft. Outer 75 ft-7.0 ft.

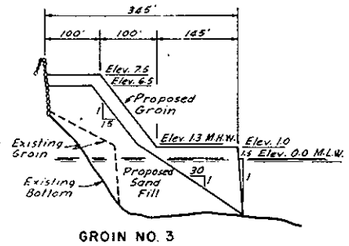
Stone Sizes
Armor: Inner 175 ft.-1.0 to 1.5 tons Outer 75 ft - 3.5 to 4.5 tons
Core: Outer 50 ft. only, quarry run stone of assorted sizes up to 900 pounds with not less than 50% from 700 to 900 pounds. No core inner section due to space limitation

PROFILES OF PROPOSED EAST JETTY EXTENSION GROIN RECONSTRUCTION AND SAND FILL AT FALMOUTH HEIGHTS

SCALE IN FEET
HOR. 100 0 100 200 300
VER. 5 0 5 10 15



GROIN NO. 2 (NO. 1 SIMILAR)



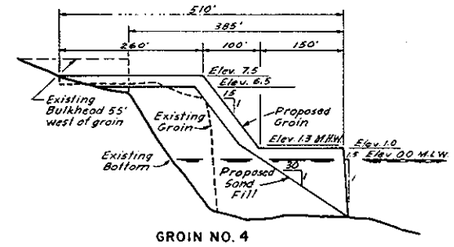
GROIN NO. 3

GROIN DETAILS - ACAPESKET

	Groin No. 2	Groin No. 3	Groin No. 4
Side Slopes	1 Vertical to 1.5 horizontal		
Top width *	Inner 95' - 5.0'	Inner 80' - 5.0'	Inner 230' - 5.0'
	Outer 250' - 7.0'	Outer 245' - 7.0'	Outer 260' - 7.0'
Armor Stone	Inner 115'	Inner 100'	Inner 250'
	1.0 to 1.5 tons		
	Outer 250'	Outer 245'	Outer 260'
	3.0 to 3.5 tons		
Core Stone**	Outer 240'	Outer 220'	Outer 260'
	Quarry run of assorted sizes up to 700 lbs. with not less than 50% from 600 to 700 lbs.		

* Transition 20' long from 5.0' to 7.0' width from inner to outer sections.

** No core along inner sections at existing groins due to space limitations.



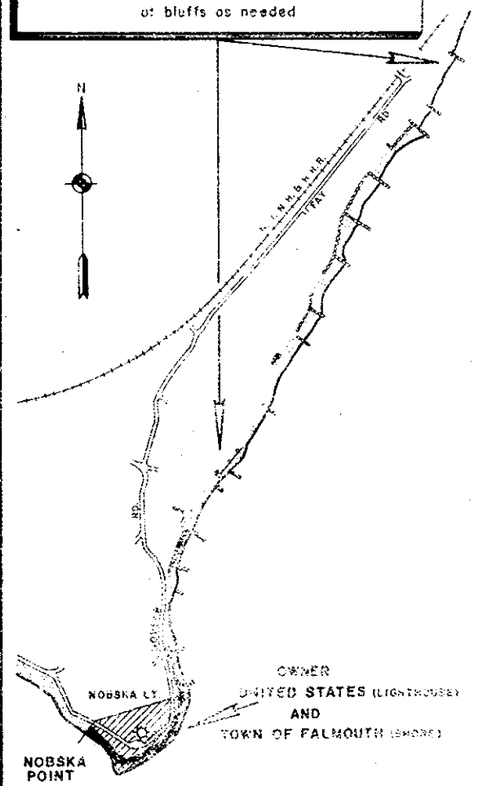
GROIN NO. 4

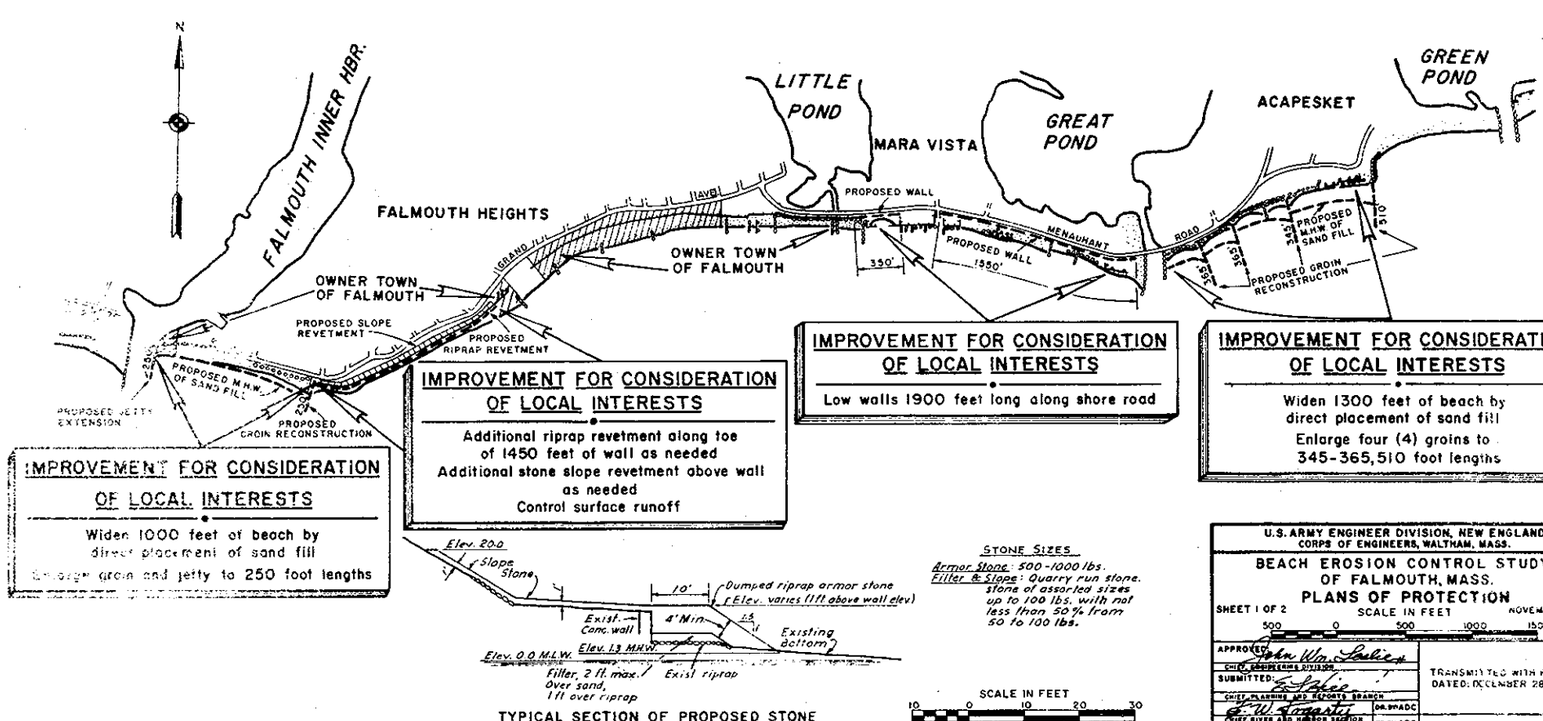
PROFILES OF PROPOSED GROIN RECONSTRUCTION AND SAND FILL AT ACAPESKET

SCALE IN FEET
HOR. 100 0 100 200 300
VER. 5 0 5 10 15

IMPROVEMENT FOR CONSIDERATION OF LOCAL INTERESTS

Stone mounds and slope revetment at bluffs as needed





IMPROVEMENT FOR CONSIDERATION OF LOCAL INTERESTS

Widen 1000 feet of beach by direct placement of sand fill
Enlarge groin and jetty to 250 foot lengths

IMPROVEMENT FOR CONSIDERATION OF LOCAL INTERESTS

Additional riprap revetment along toe of 1450 feet of wall as needed
Additional stone slope revetment above wall as needed
Control surface runoff

IMPROVEMENT FOR CONSIDERATION OF LOCAL INTERESTS

Low walls 1900 feet long along shore road

IMPROVEMENT FOR CONSIDERATION OF LOCAL INTERESTS

Widen 1300 feet of beach by direct placement of sand fill
Enlarge four (4) groins to 345-365,510 foot lengths

TYPICAL SECTION OF PROPOSED STONE PROTECTION AT FALMOUTH HEIGHTS

STONE SIZES

Armor Stone: 500-1000 lbs.
Filter & Slope: Quarry run stone. stone of assorted sizes up to 100 lbs. with not less than 50% from 50 to 100 lbs.

SCALE IN FEET
10 0 10 20 30

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

BEACH EROSION CONTROL STUDY OF FALMOUTH, MASS.
PLANS OF PROTECTION

SHEET 1 OF 2 — SCALE IN FEET 500 0 500 1000 1500 — NOVEMBER 1962

APPROVED: John Wm. Leslie, CHIEF, ENGINEERING DIVISION
SUBMITTED: [signature], CHIEF, PLANNING AND REPORTS BRANCH
[signature], CHIEF, RIVER AND HARBOR SECTION
Harry S. Andrews, PROJECT ENGINEER
DR. BY ADC
TR. BY ADC
CH. BY HSP

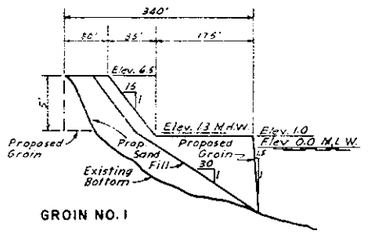
TRANSMITTED WITH REPORT DATED: DECEMBER 28, 1962

FILE NO. B E MASS. 35

PLATE NO. 11

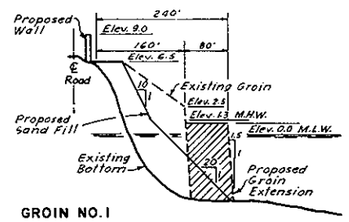
CORPS OF ENGINEERS

U. S. ARMY



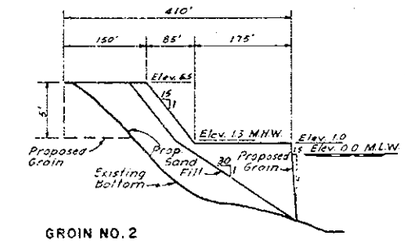
GROIN NO. 1

GROIN AND JETTY DETAILS-DAVISVILLE			
	Groin No. 1	Groin No. 2	Jetty
Side Slopes	1 vertical to 1.5 horizontal		
Top Width *	Inner 145'-5.0' Outer 115'-7.0'	Inner 195'-5.0' Outer 195'-7.0'	Inner 300'-5.0' Outer 210'-7.0'
Armor Stone	Inner 165' 1.0 to 1.5 tons	Inner 215'	Inner 320'
	Outer 175' 3.5 to 4.5 tons	Outer 195'	Outer 210'
Core Stone	Inner 165' Quarry run of assorted sizes up to 300 lbs with not less than 50% from 200 to 300 lbs.	Inner 215'	Inner 320'
	Outer 175' Quarry run of assorted sizes up to 900 lbs. with not less than 50% from 700 to 900 lbs.	Outer 195'	Outer 210'
	* Transition 20' long from 5.0' to 7.0' width from inner to outer sections		

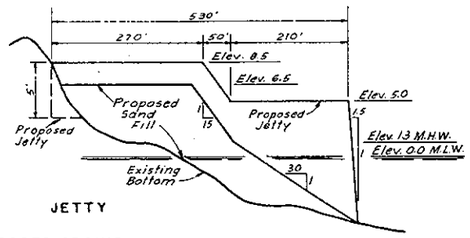


GROIN NO. 1

GROIN DETAILS-MENAUHANT			
	Groin No. 1	Groin No. 2	Groin No. 3
Side Slopes	1 vertical to 1.5 horizontal		
Top Width *	Outer 60'-7.0'	Inner 35'-5.0' Outer 225'-7.0'	Inner 40'-5.0' Outer 210'-7.0'
Armor Stone		Inner 55' 1.0 to 1.5 tons	Inner 60'
	Outer 80'	Outer 225' 3.5 to 4.5 tons	Outer 210'
Core Stone * *	Outer 80' Quarry run of assorted sizes up to 900 lbs with not less than 50% from 700 to 900 lbs	Outer 150'	Outer 70'
	* Transitions 20' long from 5.0' to 7.0' width from inner to outer sections.		
	* * No core along inner sections at existing groins due to space limitations.		



GROIN NO. 2



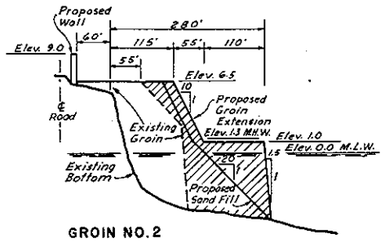
JETTY

PROFILES OF PROPOSED GROINS
JETTY AND SAND FILL AT DAVISVILLE

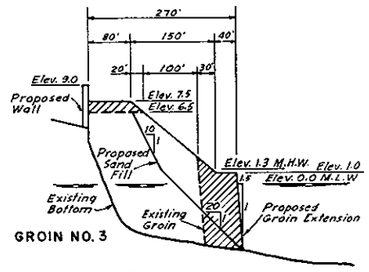
SCALE IN FEET

HOR. 100 0 100 200 300

VER. 5 0 5 10 15



GROIN NO. 2



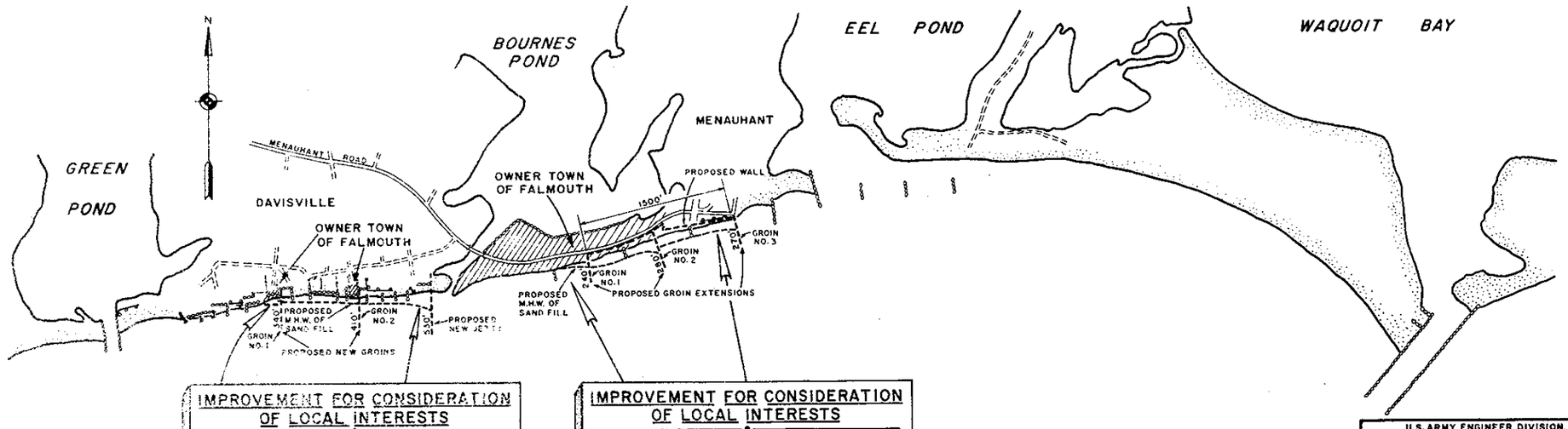
GROIN NO. 3

PROFILES OF PROPOSED GROIN RECONSTRUCTION
SAND FILL, AND WALL AT MENAUHANT

SCALE IN FEET

HOR. 100 0 100 200 300

VER. 5 0 5 10 15



IMPROVEMENT FOR CONSIDERATION OF LOCAL INTERESTS

Widen 1500 feet of beach by direct placement of sand fill

Two groins 340 and 410 feet long

Jetty 530 feet long

IMPROVEMENT FOR CONSIDERATION OF LOCAL INTERESTS

Widen 1600 feet of beach by direct placement of sand fill

Enlarge three groins to 240-280-270 foot lengths

Low wall 1500 feet long

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

BEACH EROSION CONTROL STUDY OF FALMOUTH, MASS.
PLANS OF PROTECTION

SHEET 2 OF 2 — SCALE IN FEET — NOVEMBER 1962

500 0 500 1000 1500

APPROVED: Chief, Engineering Division

SUBMITTED: Chief, Planning and Reports Branch

Chief, River and Harbor Section

Project Engineer

DR. BY: ADC

TA BY: ADC

CK. BY: HSP

TRANSMITTED WITH REPORT DATED: DECEMBER 28, 1962

FILE NO. B.E. MASS. 35

PLATE NO. 12

BEACH EROSION CONTROL REPORT ON COOPERATIVE STUDY OF

FALMOUTH, MASSACHUSETTS

Table of Contents

Subject

Syllabus

Photographs

Appendices

Appendix	Subject

Appendices (Cont'd)

Plates

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 Trapelo Road
Waltham 54, Mass.

NEDGW

SUBJECT: Beach Erosion Control Report on Cooperative Study of Falmouth, Massachusetts

TO: Chief of Engineers
Department of the Army
Washington 25, D. C.

SYLLABUS

This study covers the Vineyard Sound shore of the town of Falmouth, Massachusetts between Nobska Point and the Waquoit Bay entrance. The purpose is to determine the best method of restoring and stabilizing beaches and stabilizing the bluff areas.

The Division Engineer finds that erosion of beaches and bluffs and storm damages to shore roads and the coastal development have occurred from wave attack. A large part of the shore is particularly vulnerable to damages since it consists of low barrier bars subject to overtopping during storms and hurricanes accompanied by high tides. Protective works constructed around Nobska Point since initiation of this study now provide adequate bluff protection for that former problem area.

The Division Engineer has developed practicable plans for protection and improvement of shore areas, as follows:

a. Between Nobska Point and Falmouth Beach. - Construct stone mounds or stone revetment wherever needed for bluff protection.

b. Between Falmouth Inner Harbor and Bluffs at Falmouth Heights. - Widen 1,000 feet of beach by direct placement of sand fill, lengthen Falmouth Harbor East Jetty and enlarge existing groin.

c. Falmouth Heights Bluffs. - Place additional riprap revetment along the toe of approximately 1,450 feet of wall, place stone revetment on approximately 750 feet of slope above the wall and control surface runoff wherever needed.

d. Mara Vista. - Construct low walls, approximately 1,900 feet long along the seaward side of the shore road.

e. Acapesket. - Widen 1,300 feet of beach by direct placement of sand fill, enlarge and lengthen four (4) existing groins.

f. Davisville. - Widen 1,500 feet of beach by direct placement of sand fill, construct a jetty and two groins.

g. Menauhant. - Widen 1,600 feet of beach by direct placement of sand fill, construct a low wall 1,500 feet long and enlarge and lengthen three (3) existing groins.

Direct placement of sand fill along the shore or in stockpiles to be distributed by wave action for nourishment of beaches, or reconstruction or relocation of low shore roads at a higher elevation are suitable methods for providing protection or improvement for some locations. Complete protection of low shore areas by high seawalls or other barriers against overtopping during severe storms or hurricanes is not warranted by the limited developments which would benefit.

Since the public interest required by Public Law is insufficient to warrant Federal participation in the cost of construction of the projects considered, the Division Engineer recommends that no project be adopted by the United States for the protection or improvement of the shores of Falmouth, Massachusetts. It is further recommended that protective measures which may be undertaken by local interests, based upon their determination of economic justification be accomplished in accordance with plans and methods considered in this report.

BEACH EROSION CONTROL REPORT ON COOPERATIVE STUDY OF

FALMOUTH, MASSACHUSETTS

PART I-GENERAL

1. Authority. - This study was made by the Corps of Engineers, United States Army, in cooperation with the Division of Waterways of the Massachusetts Department of Public Works under Authority of Section 2 of the River and Harbor Act approved 3 July 1930 as amended and supplemented. The formal application for the study dated 12 February 1959, was approved by the Chief of Engineers on 26 March 1959.

2. Purpose. - The purpose of the study as stated in the formal application is to determine the best method of restoring and stabilizing beaches and stabilizing the bluff areas.

3. Prior Reports. - There have been no prior beach erosion control reports covering the study area. There have been reports on navigation studies at Falmouth Harbor within the study area and at Woods Hole adjacent to the study area which resulted in adoption of Federal navigation projects.

4. Description. - The study area is in Barnstable County along the south or Vineyard Sound shore of the town of Falmouth between Nobska Point and the east limit of the town at the Waquoit Bay entrance. It is approximately 74 miles south of Boston, Massachusetts and 39, 53 and 63 miles, respectively, east of New Bedford and Fall River, Massachusetts and Providence, Rhode Island. The location is included on United States Coast and Geodetic Survey Charts 1209, 259 and 249, on the Onset and Falmouth Quadrangles of the United States Geological Survey and on Plate 1 of this report.

5. The permanent 1960 population of Barnstable County was 70,826 and of the town of Falmouth was 13,077, each approximately 50 percent higher than in 1950. The population of the town of Falmouth is increased about 40,000 during the summer.

6. The study area is 7.8 miles long of which approximately 2.0 miles are owned by the town of Falmouth and 5.8 miles are privately owned. The town property consists of 0.24 mile of revetted bluff bordering the shore road at Nobska Point, 0.26 mile of narrow beach fronting the railroad right-of-way west of Oyster Pond, 0.46 mile of public bathing beach bordering Surf Drive east of Salt Pond, 0.65 mile of public bathing beach at Falmouth Heights, street ends at Davisville and 0.35 mile of public bathing beach at Menauhant. All but the easterly 1.1 miles of shore are accessible over State, town

or private roads. Much of the shore is closely paralleled by town roads. Washburn Island, containing the easterly 1.1 miles of shore is completely surrounded by water and can be reached only by boat.

7. Development along the shore consists of a United States Coast Guard Station at Nobska Point, widely spaced residences between Nobska Point and Oyster Pond, small summer cottages on the beach fronting Salt Pond, and residences, inns, and other seasonal accommodations behind the beach east of Salt Pond to Little Pond with the development extending about one mile inland encompassing the business section of the town along Highway Route 28, and a commercial section of the town around Falmouth Harbor associated with boating and fishing. Residential development, largely seasonal, also exists along the shore to the east of Little Pond at Mara Vista, Acapesket, Davisville and Menauhant. The shore of Washburn Island and most of the low barrier bars or spits fronting Eel, Bournes, Green, Great and Little Ponds are undeveloped. More detailed descriptive information concerning the development and composition of beaches is included in Appendix A. Bacterial tests of samples of water from the beaches indicate that the usability of the beaches is not impaired by pollution which would endanger the health of bathers.

8. Statement of the Problem and Improvement Desired. - The problem consists of erosion of bluffs and beaches and storm damages to shore roads and the coastal development from wave attack. At the time of application for the study, the serious erosion of the bluff at Nobska Point and the rapid erosion and loss of beach fill placed along the west end of the Falmouth Heights public beach from the dredging of Falmouth Harbor in 1957 were of greatest concern. Erosion and storm wave attack constitute problems along the entire study area as indicated by the numerous groins, jetties, stone mounds, walls and revetments which have been constructed for protection of beaches, roads, cottages, residences and inlets. A large part of the shore is particularly vulnerable to damages since it consists of low barrier bars which are subject to overtopping during storms and hurricanes accompanied by high tides. Such areas front Oyster, Salt, Little, Great, Green, Bournes and Eel Ponds. The shore development is generally concentrated on low land behind the beaches between the ponds and it is subject to damages from overtopping of the beaches and erosion of the land. Erosion of the bluff at Falmouth Heights endangers the shore road. Protection against the former serious erosion of the bluff at Nobska Point was provided by construction of a stone mound and riprap slope protection during 1959.

9. The needs and views of the cooperating agency and town officials concerning protection and improvement of the shores were obtained through correspondence and meetings during the conduct of the study. A joint meeting was held on 3 August 1962 attended by the engineering representative of the cooperating agency, the Town

Selectmen, the Town Engineer and members of the Town Waterways Committee at which shore problems and methods of protection were discussed. Suggestions by local interests were made as follows:

a. Maintenance of the shore could be effected by periodic placement of sand in stockpiles at locations from which the sand would be transported eastward by littoral currents to nourish the beaches thereby preventing their continued erosion and recession. This method would require the use of jetties or other littoral barriers at the west sides of inlets to impound the drifting sand. Separate stockpiles would be needed for physiographic units of shore between inlets.

b. The east jetty at Falmouth Inner Harbor could be lengthened to reduce loss of beach sand from the Falmouth Heights shore and consequent shoaling of the Falmouth Inner Harbor entrance.

c. Reconstruction of the highway bridge over the Bournes Pond Inlet and the shore road along Menauhant Beach east of the bridge is needed to permit adequate protection against recurring storm damages. The bridge and road should be rebuilt at a higher elevation at a location farther landward than at present. There is publicly owned land available on which the bridge and road could be relocated.

d. Methods of keeping the Siders Pond drainage culvert open are desired. A sandy barrier bar forms between the two existing stone jetties which flank the culvert and this blocks the drainage.

PART II - FACTORS PERTINENT TO THE PROBLEM

10. Geomorphology. - The shore line consists mostly of marine deposits in the form of a chain of sandy baymouth bars fronting ponded erosional furrows or kettle holes. It is situated on the sea margin, about 12 miles south of the apex of a triangular plain composed largely of stratified sands grading surficially from coarser near the apex to finer at the base. The apex is at the Cape Cod Canal at the intersection of two terminal moraines, one extending southwestward paralleling the Buzzards Bay shore to Nobska Point, the other southeastward paralleling the north or Sandwich shore of the inner arm of Cape Cod. The chain of baymouth bars extends eastward from the protruding glacial till headland at Nobska Point to a glacial till hill at Falmouth Heights and thence eastward, generally as a smooth shoreline to the terminus of the study area at Waquoit Bay, interrupted by inlets to the tidal ponds. A more detailed description is contained in Appendix B.

11. Littoral Materials. - a. Characteristics. - Character of littoral materials was determined from surface samples taken along seven (7) beach profiles spaced throughout the study area. The results of the sample analyses are included in Appendix C. Determination of character of materials at selected profiles and in Falmouth Inner Harbor, Great, Green, Bournes and Eel Ponds, and Waquoit Bay was made by probings. Locations of probings and material encountered are shown on Plates 2, 3 and 4. General descriptive information concerning composition of beaches, obtained by visual inspection, is included in Appendix A. The samples indicated that littoral materials consisted principally of medium sand along the easterly portion of the study area at Washburn Island, Menauhant and Acapesket, medium and fine sand in the central portion at Falmouth Heights and Falmouth Public Beach at Surf Drive and gravel, medium and fine sand along the western end of Falmouth Beach. At Nobska Point it consisted of gravel above low water and medium and fine sand below low water. Considerable quantities of gravel existed on all profiles, the largest amounts in the onshore part of the profiles at the ends of the study area and in the offshore part in the central area. Probings in Falmouth Harbor, the ponds and Waquoit Bay indicated that the material consisted of layers of mud and sand. Probings in the offshore on Profiles 2, 8, 16, 18, 20 and 22 indicated that the material consisted of sand and gravel with some mud at Profile 8. Only a small amount of penetration to refusal or hard sand was obtained on the offshore probings.

b. Sources. - Glacial deposits constitute the principal source of beach materials. Materials eroded from the glacial till headland at Nobska Point, the glacial till hill at Falmouth Heights and from the sandy deposits comprising the prongs between the bays and ponds have been transported by littoral currents and have formed the existing beaches. These original sources of beach building materials have been largely eliminated by the construction of protective works. Placement of fill along the shore from the dredging of harbor and pond improvements has in recent years constituted an important source of material. Samples and probings and experience with dredging operations indicate that sources of material suitable for nourishment of beaches by hydraulic dredging exist in the ponds and bays and in Vineyard Sound.

12. Littoral Forces. - a. Waves. - The shoreline is directly exposed to waves from the Atlantic Ocean through the four mile wide Vineyard Sound opening to the southwest, the ten mile wide Nantucket Sound opening between Monomoy Point and Nantucket Island to the east and the seven mile wide Nantucket Sound opening between Martha's Vineyard and Nantucket Island to the southeast. Wave sizes from these directions are reduced considerably by the limited fetch width through Vineyard Sound and by the shoals at the Nantucket Sound

entrances. The shoreline lies in the lee of the mainland from the north and northeast and to a lesser extent from the west. Martha's Vineyard, four miles to the south and Nantucket Island and Monomoy Island 30 miles to the southeast and east, respectively, provide some shelter from these directions. No wave measurements are available for the immediate area. A wave rose based on synoptic weather charts prepared by the Beach Erosion Board for a deep water location off Nauset Beach, Cape Cod, Massachusetts is shown on Plate 1. It indicates that waves off Nauset Beach occur with greatest frequency from the northeast and east and that waves from the southerly directions, to which the shoreline is more directly exposed, occur with a considerably lesser frequency.

b. Currents. - Tidal currents flood to the east and ebb to the west. Maximum average velocities in Vineyard Sound one mile south of Nobska Point are 2.6 and 2.4 knots on the flood and ebb, respectively. In Nantucket Sound, about midway between the mainland and Martha's Vineyard, average velocities are 2.1 and 2.2 knots on the flood and ebb, respectively. Tidal currents at Falmouth Harbor, the ponds and Waquoit Bay flood northward into the inlets and ebb southward out of the inlets.

c. Winds. - Records of winds observed by the United States Weather Bureau at Nantucket, Massachusetts for a five-year period from August 1952 to July 1957 and a two-year period from August 1958 to July 1960 show that winds blow from westerly directions about two-thirds of the time and from easterly directions about one-third of the time. Onshore winds from the southwest quadrant have a slightly longer duration than from the northwest quadrant and double the duration of onshore winds from the southeast quadrant. A wind diagram based on the observed data is shown on Plate 1. A summary of the data and a more detailed description is included in Appendix D.

d. Storms. - Analysis of nine years of United States Weather Bureau records, consisting of three separate periods from 1945 to 1960, was made for winds having a continuous duration of at least four hours and a wind speed of 30 miles per hour or higher. It showed that north northeast winds occur most frequently and have the longest duration, that northeast and east northeast winds have the highest average speeds and that winds have the longest duration from the northeast quadrant. It also showed that winds have the shortest duration from onshore directions from the southeast and southwest quadrants and that winds from the southwest quadrant have a much longer duration than from the southeast. A summary of these winds is included in Appendix D, Table D-2.

e. Tides. - Tides are semi-diurnal. The mean ranges are 1.5 feet at Nobska Point, 1.3 feet at Falmouth Inner Harbor

and Falmouth Heights and 1.1 feet in Waquoit Bay. Spring ranges are 1.9 feet at Nobska Point and 1.6 feet at Falmouth Heights. The highest tide of record of 12.7 feet above mean low water occurred at Falmouth Heights during a hurricane on September 14-15, 1944. Tides 3.0 feet above mean high water probably occur about once a year. More detailed information concerning tidal observations, frequencies of occurrence and extreme tides is included in Appendix E.

13. Shore History. - a. Shoreline Changes. - High water shoreline changes during the entire period of record from 1845 to 1961 were smaller along the study area west of Falmouth Inner Harbor than to the east. There was little change at the outer tip of Nobska Point and erosion and varying amounts of shore recession, not exceeding 100 feet, along most of the shore to the east to and including Falmouth Beach except for localized areas at the west sides of groins and similar structures where impounded material caused short segments of the shoreline to move seaward. Recession of the shore, generally less than 50 feet, occurred along the shore between Falmouth Beach and Falmouth Inner Harbor except adjacent to the west Falmouth Harbor jetty where impounded material moved the shore up to about 200 feet seaward. The Falmouth Heights shore was eroded between 1845 and 1941 resulting in landward shore movements of up to about 150 feet but during 1961, as a result of direct placement of sand on the beach during 1957, and subsequent drifting, parts of this shore were up to about 150 feet seaward of their 1941 position. From 1845 to 1961, the Mara Vista shore moved 50 to 100 feet landward, the Acapesket shore receded 150 to 500 feet, the greater recession along the easterly third of the area, the Davisville shore receded 100 to 400 feet, the larger movement at the west end, the Menauhant shore receded 100 to 250 feet and the Washburn Island shore moved landward along its west half up to about 700 feet and the shore along the east half moved seaward up to about 500 feet, the latter accretion as a result of impounding of material at the Waquoit Bay west jetty. Changes in recent years (from 1938-1942 to 1961) have been influenced by the construction of various types of protective works. Large or significant changes during this period have consisted of accretion at the west sides of groins between Nobska Point and Falmouth Beach, at the west side of the Falmouth Inner Harbor west jetty, along most of the Falmouth Heights shore, at the west side of the Waquoit Bay west jetty and recession at the east and west ends of the Acapesket shore and at the west end of the Washburn Island shore at the Eel Pond entrance.

b. Offshore Depth Changes. - Movements of offshore depth contours were irregular and of a magnitude to indicate that offshore depth changes were generally small. Changes in the vicinity of various depths were as follows: Plus signs indicate shoaling and minus signs deepening.

Location	Period	DEPTH			
		6-Foot	12-Foot	18-Foot	30-Foot
Nobska Point	1938-1961	No significant changes			
Nobska Point to Falmouth Beach	1887-1938	+	±	-	-
	1938-1954	No significant changes			
	1954-1961	+	+	+	+
Falmouth Beach	1887-1938	-	-	±	+
	1938-1961	No significant changes			
Falmouth Beach to Falmouth Hbr	1887-1961	-	-	-	-
Falmouth Heights	1845-1938	-	-	±	±
	1938-1961	-	-	-	-
Mara Vista	1845-1938	-	-	+	+
	1938-1961	-	-	-	No change
Acapesket	1845-1938	-	-	-	±
	1938-1961	-	No change	+	+
Davisville and Menauhant	1845-1931	±	+	+	+
	1938-1961	-	+	±	No change
Washburn Island	1845-1938	No information			+
	1845-1961	No change	-	+	+

c. Prior Corrective Action and Existing Structures. - Many protective works have been constructed throughout the study area over a long period to prevent erosion of beaches and bluffs, to prevent storm damages, to restore losses of beach materials and to stabilize inlets. Structures consist of the following: a stone mound, slope revetment and groins of Nobska Point; stone walls, revetment and groins and timber bulkhead and piers between Nobska Point and Falmouth Beach; stone groins, jetties, breakwaters and revetment, timber piers and a concrete and steel bulkhead at Falmouth Beach;stone mounds, walls, groins and revetment and concrete groins and walls between Falmouth Beach and Falmouth Inner Harbor; stone jetties at the entrances to Falmouth Inner Harbor, Little Pond, Great Pond, Green Pond, Eel Pond, and Waquoit Bay; mortared and dumped stone revetment, stone and concrete groins and concrete walls at Falmouth Heights; stone groins and revetment, concrete walls, timber groins, bulkhead and piles at Mara Vista; stone groins, revetment and mound, precast concrete block wall

and timber piles and bulkhead at Acapesket; stone groins, mounds and revetment, timber groins, bulkheads and piles, and concrete groins at Davisville; stone groins, revetment and mound and timber bulkheads and groins at Menauhant; stone groins at Washburn Island. Sand fills have been placed west of the Falmouth Harbor entrance, along Falmouth Heights, Mara Vista, Acapesket and Menauhant. More detailed information concerning these structures and beach fills is included in Appendix G. Existing structures are shown on Plates 2, 3, and 4.

d. Beach Profiles. - Beach profiles were surveyed during 1961 at twenty-four selected locations throughout the study area as shown on Plates 2, 3, and 4. Plots of the profiles are shown on Plates 5 to 8, inclusive. A more detailed description of the profiles, a tabulation of the slopes on individual profiles and their principal characteristics at the various beaches is included in Appendix H. Due to lack of comparative surveys, seasonal changes of beach slopes could not be determined. There were large and irregular variations of beach slopes along the shore. Heights of beach berms above the plane of mean low water, where they existed were as follows: Washburn Island, 6.5 feet; Falmouth Heights between 5.0 and 6.0 feet; Falmouth Beach 6.5 feet; and between Nobska Point and Falmouth Beach, 6.0 feet. The steeper portions of the profiles seaward of the berms or upper portions of the beaches to below low water had slopes as follows: Washburn Island one vertical to 10 or 12 horizontal (1/10 to 1/12); Menauhant, 1/3; Davisville 1/44 east portion, 1/9 west portion; Acapesket 1/16; Mara Vista 1/6, east portion, 1/11 west portion; Falmouth Heights, 1/6 to 1/12, east half, 1/20 to 1/28 west half; Falmouth Harbor to Falmouth Beach, 1/12; Falmouth Beach, 1/10 to 1/15; Nobska Point to Falmouth Beach, 1/7 to 1/10, east portion, 1/22 to 1/36 west portion; Nobska Point 1/20. Profiles generally leveled off to slopes flatter than 1/100 at depths of 3 to 10 feet along Falmouth Beach and the shore to the east and at greater depths, up to 28 feet, west of Falmouth Beach.

e. Volumetric Accretion and Erosion. - Volumetric changes along the Falmouth Heights shore were estimated from shoreline surveys run by the town of Falmouth during October 1947, June and December 1957 and November 1958 and from a survey run for this study during July 1961. Volumes were estimated based on the assumption that beach slopes in all periods were similar to those determined from the 1961 survey of beach profiles. Accretion is attributed to hydraulic fill placed on the beach during 1957. Fill placement was completed during early May 1957. Fill was placed directly on the beach between the existing groins at Stations 198+50 and 216+50 and subsequently drifted eastward. Volumetric changes estimated between October 1947 and June 1957 are believed to have occurred principally during the first half

of 1957 as a result of placement and drifting of fill. Total changes and rates of change per linear foot of shore per year are given below from west to east for the five compartments of shore formed by existing groins.

Volumetric Changes - Falmouth Heights

Location	Volume	
	Cubic Yards	Cubic Yards Per Linear Foot/Year
Sta. 198+50 to Sta. 216+50		
June 1957 to Dec. 1957	-28,060	-31.2
Dec. 1957 to Nov. 1958	-29,920	-18.1
Nov. 1958 to July 1961	-10,020	- 2.1
June 1957 to July 1961	-68,000	- 9.2
Sta. 216+50 to 220+0		
Oct. 1947 to June 1957	+17,700	-
June 1957 to July 1961	Minor	0.0
Oct. 1947 to July 1961	+17,700	-
Sta. 220+0 to 224+0		
Oct. 1947 to Nov. 1958	+17,700	-
Nov. 1958 to July 1961	+ 2,940	+ 2.8
Oct. 1947 to July 1961	+20,640	-
Sta. 224+0 to 227+80		
Oct. 1947 to Nov. 1958	+ 5,900	-
Nov. 1958 to July 1961	+ 6,000	+ 5.9
Oct. 1947 to July 1961	+11,900	-
Sta. 227+80 to 233+40		
Oct. 1947 to Nov. 1958	+ 2,600	-
Nov. 1958 to July 1961	+16,100	+10.8
Oct. 1947 to July 1961	+18,700	-

The westerly compartments of shore filled or nearly filled by drifting at an earlier date than those to the east. The rate of filling increased to the eastward for the later period after November 1958 evidently due to the availability of impounding capacity and the passage of sufficient time for drifting sand to fill compartments to the west and reach those to the east.

PART III - ANALYSIS OF PROBLEM

14. Shore Processes Pertinent to the Problem. - The principal past sources of beach materials have been the eroding headlands within the area. Eroded materials have moved generally eastward forming baymouth bars across the pond entrances. Protection of the eroding bluffs has practically eliminated the supply of beach-building materials therefrom with resultant recession of the beaches. There is no apparent predominant direction of littoral drift along the central and western part of Falmouth Beach and the shore to the west to Nobska Point. East of Falmouth Beach to Waquoit Bay, the greater accumulation of beach material at the west sides of jetties and groins is visible evidence of predominant eastward movement. Occasional accumulations at the east sides of groins indicate that the direction of movement of littoral drift varies. The rate of loss of beach material generally exceeds the rate of supply. Due to the absence of natural sources of supply and the existence of numerous groins, the quantity of littoral drift is small. Volumetric accretion at the Waquoit Bay west jetty estimated from comparative shoreline changes from 1938 to 1961 was about 4,000 cubic yards per year. Eastward movement of littoral drift along the study area was, therefore, at least of that magnitude. A larger rate of loss occurred at Falmouth Heights for a short period where comparative surveys show a loss of 28,000 cubic yards of fill from the area of placement during six months in 1957. Movement of material is largely along shore. Material also moves landward over the low barrier beaches and is probably also lost offshore. The greatest losses occur as a result of short period waves during storms. Some recovery of beach losses probably occurs as a result of swells during calmer periods. The loss of protective beaches is gradually exposing developed areas to more severe wave attack and damages.

15. Methods of Correcting Problem Conditions. - In general, the rate of supply of beach material cannot be increased except by artificially placing material directly on the beaches or in stockpiles to be distributed by wave action. Probings indicate that suitable material is available offshore or in the ponds within a practicable distance for hydraulic dredging and placement on the beaches. Widening the beaches in this manner is an effective method for restoring past losses, improving beaches for recreational use and providing protection for developed areas against wave attack. The inadequacy of the supply of material feeding the beaches and the existence of jetties at most inlets necessitate compartmentation of the shore and consideration of separate plans for shore segments. Although protection of eroding bluffs has reduced sand supply to beaches, compartmentation of the shore by jetties and groins has reduced losses from beaches and use of past rates of erosion in determining future nourishment requirements of restored or protected beaches is probably valid.

Numerous groins and jetties constructed along the shore have proven to be effective in reducing losses of beach material. Loss of land and damages to developed areas have been prevented, except during the most severe storms and hurricanes, by armoring the shore with sea walls, revetments and bulkheads in these areas where the supply of material has been inadequate to maintain a protective beach. Such structures have reduced the supply of material available for beaches by protecting former sources of supply. Landward movement of material over low beach areas can be prevented or reduced by raising shore roads or constructing seawalls or other barriers. Other methods of protection, such as offshore breakwaters, are not considered applicable.

16. Design Criteria. - Proposed protective measures are designed to provide protection for ordinary conditions of comparatively frequent occurrence (about once a year). They are not intended to provide complete protection in the event of hurricanes or great storms of infrequent occurrence, although even under these conditions some protection will be afforded.

a. Design Tide. - The design tide is the highest tide which occurs on an average about once a year. The elevation of the design tide is 3.0 feet above the plane of mean high water.

b. Design Wave. - The height of the design wave was determined from the relationship $d/H=1.28$ where d is the depth of breaking and H is the height of wave at breaking using the depth at or a short distance seaward of the proposed structure at time of design tide as the depth of breaking.

c. Sizes and Slopes of Armor Stones in Structures. - Sizes and slopes of armor stones for groins, jetties and stone revetments are computed using the United States Army Waterways Experiment Station Formula as described in Technical Report No. 4 of the Beach Erosion Board entitled "Shore Protection Planning and Design."

d. Sand Fills. - The berm elevation of proposed beach fills is based on those at existing beaches in the study area. The minimum width of fill above mean high water is based on widths found to afford protection in the area. Estimated volumes of fill are based on slopes similar to existing slopes but fill can be placed initially to a steeper slope and permitted to take a more natural slope under wave action. Based on these criteria the beach width between the seawall and the high water shoreline is 125 feet, the berm elevation is 6.5 feet above mean low water and the fill slopes vary from 1 on 10 to 1 on 30 in accordance with existing slopes. Suitable sand for beach fills would have size and gradation characteristics similar to those of existing

beach materials. For the purpose of detailed design of the beach-fill, the investigation of materials on the beach and in proposed borrow areas should be supplemented when plans and specifications are being prepared.

e. Groins and Jetties. - The horizontal shore section should ordinarily have a top elevation not lower than the general height of existing or anticipated berms of beaches and a length not less than the berm width of the anticipated beach. This minimum top elevation has been determined to be not less than 6.5 feet above mean low water and the elevation is higher for terminal groins or jetties intended to completely block passage of littoral drift or to reduce it considerably. The intermediate sloped section should not be steeper than the slope of the existing bottom. The top elevation of the outer section should not be lower than 1 foot above mean low water for groins and not lower than 5 feet above mean low water for jetties. For stone construction, the minimum height of structures should be 5 feet. This height is increased wherever necessary to permit use of armor stones that will not be displaced by wave action. The determination of armor stone sizes is described in the preceding Subparagraph c. Blankets of spalls or crushed stone are used under stone groins or jetties to minimize settlement due to scour. The ends of structures extend seaward at least to the toes of proposed fills.

PART IV - PLANS OF PROTECTION

17. General. - Plans of protection have been considered for all known beach erosion control problems throughout the study area. Detailed plans have been developed for all specific problem areas where there is a present need for protection or improvement and typical plans or methods of protection have been indicated for use in areas where it appeared that a need for protection might develop. Descriptions, problems and plans of protection for shore areas, generally divided in accordance with physical character of shore features or the limits of public ownership, are contained in the following paragraphs. The locations of these shore areas are shown on Plate No. 9.

18. Nobska Point. - Nobska Point is located at the west limit of the study area. The shore has a length of 2,200 feet including 1,250 feet around the tip of the point, owned by the town and 950 feet extending eastward from the tip, privately owned. Development, all landward of the road bordering the shore, consists of a United States Coast Guard Station behind the town property and residences behind the private shore. The outer end of Nobska Point is a glacial till headland with a steep seaward slope protected by a stone mound and riprap revetment. The sandy shore and road to the east are protected by riprap revetment and the remains of stone groins.

PHOTO 1 NOBSKA POINT TO FALMOUTH BEACH
Nov 27, 1961 - Nobska Point in foreground

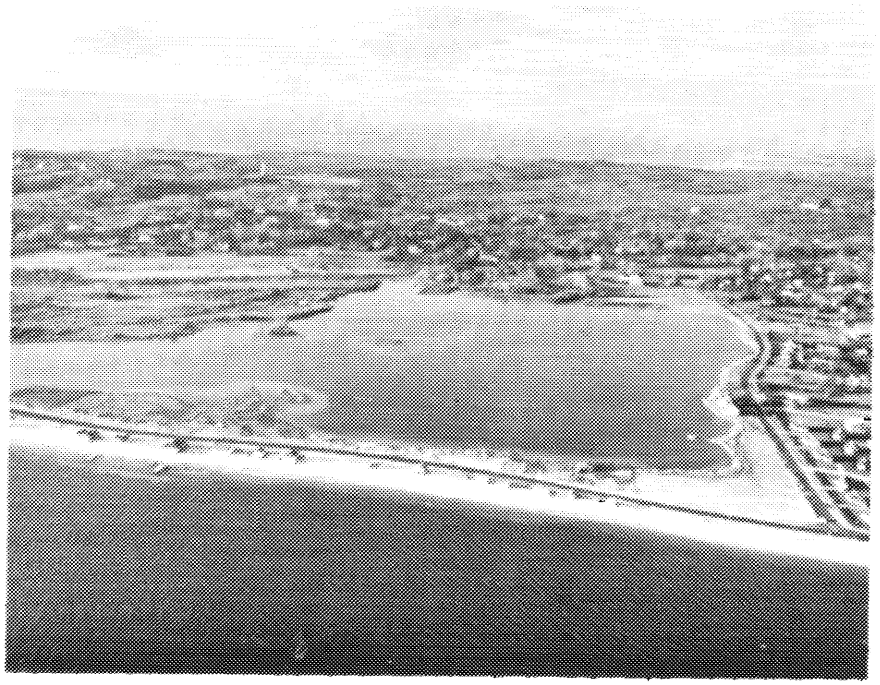


PHOTO 2 FALMOUTH BEACH (CENTRAL PORTION)
Nov 27, 1961 - Cottages on low barrier bar

Construction of the stone mound and revetment around 1,100 feet of the tip of the point during 1959 provided needed protection for the former eroding bluff and the shore road behind it. Except for maintenance of small areas where a few stones were displaced, apparently the result of loss of the underlying sand and gravel, no additional work is needed around the tip of the point. The elevation of the road, which closely borders the shore, drops to the east and it is subject to overtopping during high storm tides. This does not create a particularly serious problem since the residential development is located on higher ground well behind the shore. Protection, if desired, can be provided by reconstructing the road at a higher elevation and placement of riprap revetment along the face of the road embankment. In general, maintenance of the existing stone mound and riprap revetment should provide suitable protection for this area.

19. Between Nobska Point and Falmouth Beach. - The shore extending 5,900 feet northeastward from Nobska Point to Falmouth Beach is privately owned. Development is residential with residences widely spaced and generally located on high ground well behind the beach. The easterly 1,400 feet of shore is closely paralleled by a railroad line and residences in this area are located even farther landward. The shore is protected by a series of stone groins. Residences and glacial till bluffs behind the beach are protected by a discontinuous system of protective works consisting of low stone walls, a timber bulkhead, dumped or mortared stone revetment and stone mounds. The shore has generally receded over the period of record, since 1845, at a rate not exceeding one foot per year. In recent years, since 1941, there has been accretion in the immediate vicinity of some of the groins. The beach width above high water in front of bluffs and protective structures varies from about 30 to 125 feet. The beach is composed of medium and coarse sand and gravel with the composition coarser to the east. Existing protective works are generally suitable for protection of the beach and residential development. Some erosion occurs to the bluffs near the shore which are still unprotected. Protection can be provided by construction of stone mounds or stone revetment along the toes of bluffs as has been done at adjacent areas. Details of a typical protective stone mound are shown on Plate 11. It consists essentially of an outer layer of armor stone large enough to withstand displacement by wave attack and an underlying filter layer designed to prevent washing out of the glacial till. The size of armor stone at specific locations will depend on the size of waves which can reach the structure when the tide is at the design level and the sizes of stones in the filter layer are based on the armor stone sizes. Due to the lack of a source of supply of material

to nourish the beach by natural shore processes, it is possible that the existing sandy beach may be gradually eroded despite the construction of groins and other protective structures. In the event it becomes necessary to do so, the sandy beach can be restored, maintained or improved by the direct placement of sand fill along the shore or in stockpiles to be distributed by wave action. The choice between direct placement along the shore or in stockpiles should be based on a comparison of the costs involved. Use of stockpiles will generally be more economical only where a long reach of shore is involved. The stockpile could be placed west of the area to be improved to permit nourishment of the shore by eastward drifting. Under present conditions, there is no apparent immediate need for shore nourishment.

20. Falmouth Beach (West End). - The westerly 1,400 feet of Falmouth Beach is owned by the town of Falmouth. The public shore consists of a strip of beach on the seaward side of the railroad line with a width above mean high water of about 50 feet. The beach is largely covered with gravel with increasing amounts of sand at its surface to the east. The beach is undeveloped and directly accessible only to pedestrians across the railroad tracks from Oyster Pond Road. Dumped riprap imbedded in the beach provides some protection for the railroad tracks. The shoreline has receded at an average rate of about one-half foot per year during the period of record from 1845 to 1961. In its present undeveloped state, this erosion and shore recession does not constitute a serious problem. In the event the area is developed in the future, buildings or other structures should be located far enough landward and constructed at a high enough elevation so as to prevent or reduce damages during their intended life from continued erosion or from wave attack during storms accompanied by extreme high tides when the beach would be overtopped. Erosion of the shore can be reduced by the construction of groins as has been done along the adjacent shore to the east. Gradual loss of beach material, even if groins are constructed, may require artifical nourishment of the beach. The sand beach can be maintained or enlarged by placement of sand fill either directly on the beach or in stockpiles to be distributed by wave action. The stockpiles could be located west of the area to be improved to permit nourishment of the shore by eastward drifting. Widening of the shore by fill placement will generally require the extension of drains which cross the beach. Under present conditions of use and development, there is no apparent immediate need for either groins or shore nourishment.

21. Falmouth Beach (Central Portion). - The central portion of Falmouth Beach with a length of about 4,850 feet fronting Oyster and Salt Ponds is privately owned except for 50 feet at the jettied drainage outlet at Salt Pond which belongs to the town of Falmouth. A railroad line is located on and closely parallels the

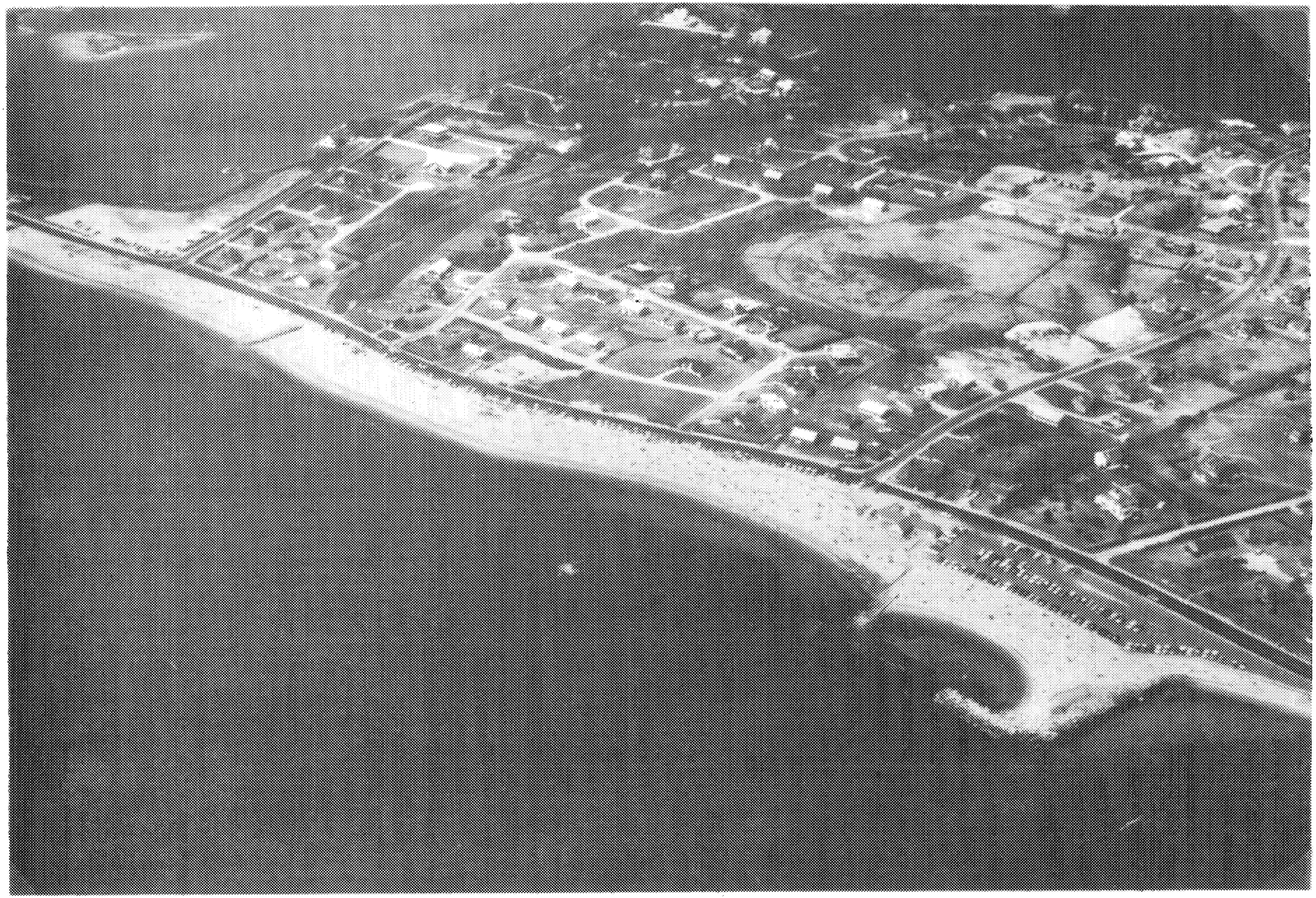


PHOTO 3 FALMOUTH BEACH (EAST END) - Aug 26, 1962. Sunday attendance at the public bathing beach.

shore for about 800 feet at its west end and a town road, Surf Drive, closely parallels the rest of the shore. There are approximately 20 summer cottages on the beach seaward of Surf Drive, most of them concentrated in front of Salt Pond. The beach is composed of medium and coarse sand and scattered layers of fine gravel deposits, the latter diminishing and ceasing at the east end of the area. The beach width above high water varies from about 70 to 140 feet in front of the railroad tracks, 20 to 100 feet fronting Surf Drive opposite Oyster Pond and the west end of Salt Pond and 60 to 160 feet fronting Surf Drive along the cottage development at the east end of the area. During the period of record from 1845 to 1961, parts of the shore receded at an average rate generally less than one foot per year. From 1941 to 1961 the shoreline position remained comparatively unchanged or it moved a small distance seaward. Some of the area is protected by a system of stone groins and jetties which have been effective in reducing or preventing shore recession. Portions of Surf Drive are fronted by dumped riprap or a low wall. Due to its narrowness and low elevation, the beach is subject to overtopping during storms and hurricanes accompanied by extreme high tides. Landward movement of large quantities of beach sand occurs as a result of wind and wave action. This material covers Surf Drive and makes it impassable. Cottages on the beach sustain damages from direct wave attack and flooding during storms or hurricanes. Under these conditions some of the cottages have been floated off their foundations to the landward side of Salt Pond from whence they have been recovered and replaced on the beach. Erosion of the beach can be effectively prevented or reduced by maintenance of existing groins. Complete protection of the development on the beach could be effected by construction of a fronting seawall, dike or some other form of high barrier. A large measure of protection could be provided by widening the existing beach, where needed, by direct placement of sand fill on the beach or in stockpiles to be distributed by wave action. Lengthening of existing groins to reduce fill losses from a widened beach would probably be necessary. Due to the type of use and the limited development involved, construction of a high fronting barrier or placement of a wider sand beach does not appear to be warranted. Raising the elevation of Surf Drive or constructing a low seawall or barrier to reduce landward movement of sand would be a suitable form of partial protection for the road and the development behind it. The beach itself is more suitable for use as a bathing area than for cottage development. It is, therefore, advisable to consider restricting it to such use.

22. Falmouth Beach (East End). - The easterly 2,350 feet of Falmouth Beach is owned by the town of Falmouth and it is used as a public bathing beach. There is a parking lot at the west end and a bathhouse and a parking lot at the east end. The shore is

bordered by a town road with residences along its landward side. The beach width between the high water line and the shore road increases eastward from about 70 to 160 feet. The beach composition is finer to the east. It consists of coarse and medium sand with the backshore partially covered with low-grassed sand dunes. Two stone jetties across the beach train the flow of a culvert which drains Siders Pond. There are two shore-connected curved stone breakwaters at the east end of this shore which act as a littoral barrier impounding a sand beach to the west. The parking lot at the bathhouse is protected by stone revetment and a bulkhead. The shoreline in 1961 was generally at or seaward of its position in 1845 indicating that the beach is stable or benefitting from accretion. The beach is in good condition. Some landward movement of sand over the shore road occurs as a result of wind or wave action but the beach is generally wide enough to protect the development landward of it from storm damages. It is possible that due to lack of a natural source of supply of beach building materials that erosion and recession of the shore may occur at some future time. In this event, the sand beach could be maintained by placement of sand fill either directly on the beach or in stockpiles located to the west to be distributed by eastward drifting. There is no present apparent need for such nourishment. Drifting of sand and formation of a sand bar between the jetties at the Siders Pond culvert periodically stops the drainage causing a problem of local concern. Correction of this problem could be effected by either seaward extension of the jetties to prevent drifting of sand around their ends or by seaward extension of the drain. Extension of the jetties or drain out to a depth of six feet would probably be adequate. The extension of the jetties by interfering with the natural drifting of sand might have an adverse effect on the adjacent shore. The drain extension would have the advantage of permitting free movement of sand along the beach over the culvert and elimination of the need for jetties.

23. Between Falmouth Beach and Falmouth Inner Harbor. - The shore extending eastward about 2,400 feet from Falmouth Beach to the west jetty at the Falmouth Inner Harbor entrance is privately owned. Development consists of residences generally located well behind the shoreline. The development and the shore are protected by a variety of structures consisting of stone mounds, riprap revetment, stone, timber and concrete groins and stone and concrete walls. Along the west end of the area a stone mound is located at the shoreline with no fronting beach. In the central portion of the area there is a sand beach about 40 feet wide fronting protective structures and this beach width increases eastward to about 150 feet at the harbor jetty. The beach is composed of coarse to medium sand, with gradation finer to the east. During periods prior to 1941, the shore, except adjacent to the west jetty, has receded up to about 1 foot per year. The west jetty, constructed in 1909 resulted

PHOTO 4 FALMOUTH HEIGHTS, Nov 27, 1961 - From Falmouth Inner Harbor entrance to bluffs.

PHOTO 5 FALMOUTH HEIGHTS, Nov 27, 1961 - The bluffs, Casino and public bathing beach

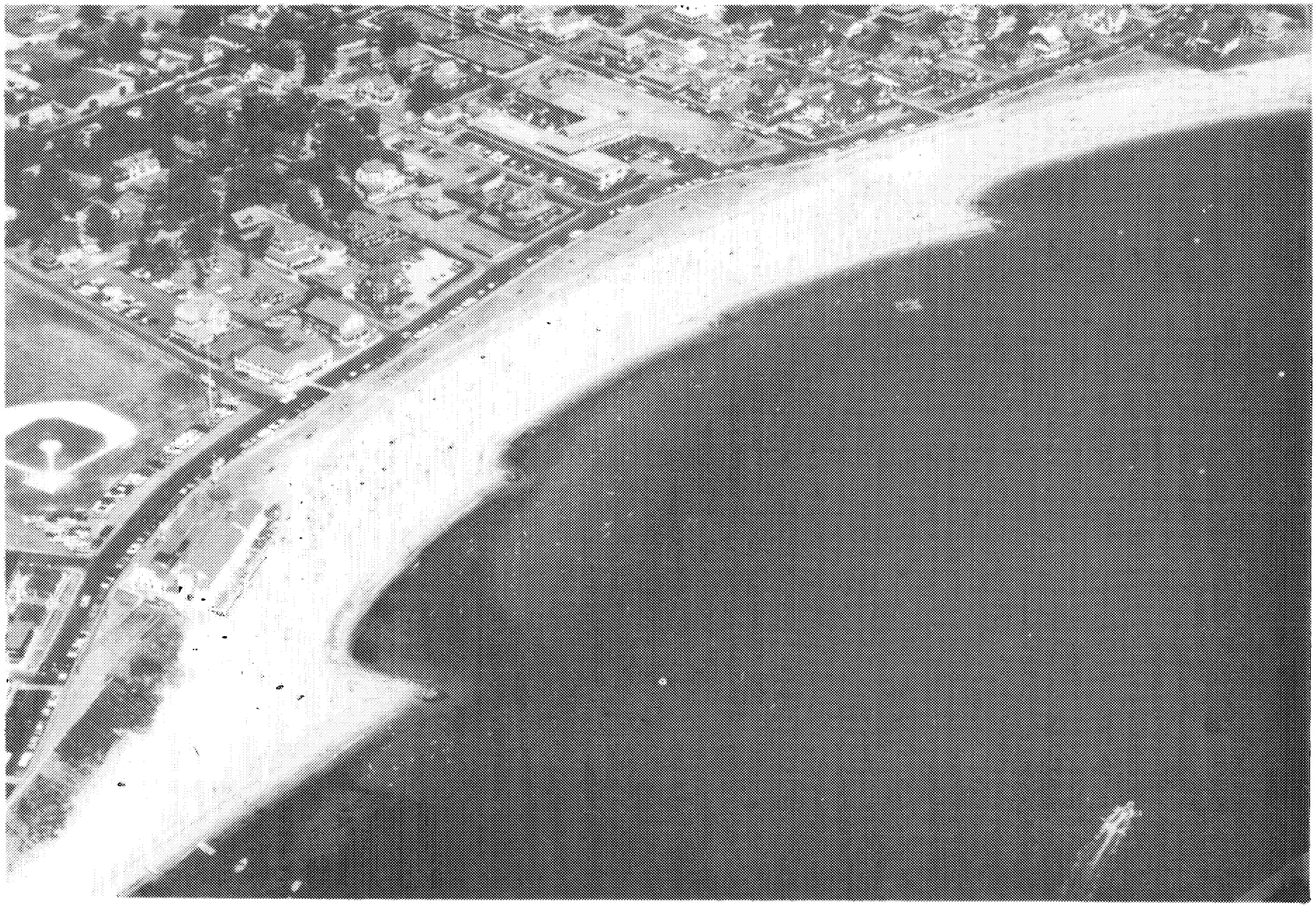


PHOTO 6 FALMOUTH HEIGHTS, Aug 26, 1962. - Sunday attendance at the public bathing beach.

in accretion adjacent to it of about 150 feet to 1941 and another 100 feet up to 1961. No other significant changes occurred within the area from 1941 to 1961 indicating that existing structures have stabilized the shore. If additional protection is desired, it can be effected by direct placement of sand fill along the shore to provide a wider sand beach. The use of a stockpile west of the area would probably not be effective due to the existence of the breakwaters at Falmouth Beach which act as a littoral barrier. Eastward drifing of sand placed along the shore could result in narrowing of the west end of the fill and filling of the west jetty at the Falmouth Inner Harbor entrance to the limit of its impounding capacity with consequent movement of sand around the jetty into the harbor entrance. Prevention of harbor shoaling under these conditions would require extension of the jetty. Eastward drifting could be reduced by construction of groins west of the jetty to hold a beach of the desired width. This might eliminate the need for extension of the jetty. Under conditions of present use, existing structures, if maintained, should provide adequate protection for the development although during exceptional storms or hurricanes overtopping and flooding could occur.

24. Falmouth Heights. - The shore of Falmouth Heights with a length of 5,450 feet borders shore roads between the Falmouth Inner Harbor east jetty and the culvert at the Little Pond inlet. The westerly 150 feet adjacent to the stone jetty is a town beach provided with a public parking area. The private bathing beach for about 1,000 feet to the east is occupied by a motel at its west end. The shore east of the motel is accessible from the shore road and it is used by the public for bathing. Mortared stone revetment protects the motel and dumped riprap protects the shore road. The town of Falmouth owns the next 3,450 feet of shore to the east except for 230 feet at a theatre, the Casino, which is private. This public shore extends around the base of the steeply sloping face of a bluff for about 1,800 feet and thence along a town bathing beach. The bluff is protected by a low concrete wall around its base with riprap along its toe and stone revetment on the slope above the wall along its eastern portion. There is a low stone groin at the west end of the bluff and another at the east end. The Casino is protected by dumped riprap. There are three stone groins along the public bathing beach and a concrete seawall fronting a park area behind it. The shore extending 850 feet east of the public bathing beach is private except for the culvert and inclosing stone jetties at Little Pond which belong to the town. The west half of this private beach is occupied by residences and the east half is an undeveloped barrier bar. The residences are fronted by concrete walls and three stone groins and the road along the barrier bar is fronted by a concrete wall or dumped riprap. Development landward of the entire Falmouth Heights shorefront consists of residences, summer hotels and inns.

25. The beach is composed of sand varying from fine to coarse and small amounts of gravel. The width above high water varies considerably. It is 70 to 80 feet along the west end with little or no beach around the base of the adjoining bluff, 90 to 165 feet along the public bathing beach and 40 to 90 feet along the private shore to the east. During different periods between 1845 and 1941, comparative shoreline locations indicate that the shore has receded about one-half to one and one-half feet per year. Due to placement in connection with a Federal navigation improvement of approximately 120,000 cubic yards of sand fill dredged from Falmouth Inner Harbor along the shore of the Falmouth Heights bluffs during 1957 and subsequent drifting, the 1961 locations of the high water line along all of the area were generally seaward of their 1941 positions. The fill was eroded rapidly from the area of placement and nourished adjacent shores. This created the present wide sandy public bathing beach east of the bluffs and probably also resulted in widening of the shore west of the bluffs. The beneficial effect which was obtained by placement of dredged fill along the shore of the bluff between Vernon and Walden Avenues during 1957 indicates that stockpiling sand at this location is a suitable method for nourshing the adjacent beaches. Therefore, it is desirable that sand fill from future harbor maintenance, estimated to average 7,500 cubic yards per year, be placed on the beach east of the entrance. The rapid erosion of fill from the area of placement indicates that sand fill placed to provide a protective beach for the bluffs would have to be replaced frequently.

26. Due to erosion and narrowing of the beach, the concrete seawall fronting the bluff is subject to damages from wave attack and undermining. Erosion of parts of the unprotected face of the bluff above the wall occurs but this erosion is due more to surface runoff than to overtopping. Protection against undermining and wave attack can be provided by placement of additional riprap along the toe of the wall. Erosion of the bluff above the wall can be prevented by interception or control of surface runoff and by extending the existing stone slope protection. A typical section showing this type of protection is shown on Plate 11.

27. Additional recreational beach area can be provided if needed for public recreational use along the private shore between Falmouth Inner Harbor and the bluffs to the east by placement of sand fill to widen the beach and enlargement of the existing groin at the east limit of the fill to reduce losses by eastward drifting. This widening would provide protection for the backshore in addition to recreational area. Enlargement of the groin, however, would decrease the supply of material to the public beach east of the bluffs until the groin was filled to the limit of its impounding capacity. Some losses of beach material occur by westward drifting around the Falmouth Inner Harbor east jetty resulting in shoaling of the harbor entrance. These losses and the harbor shoaling can

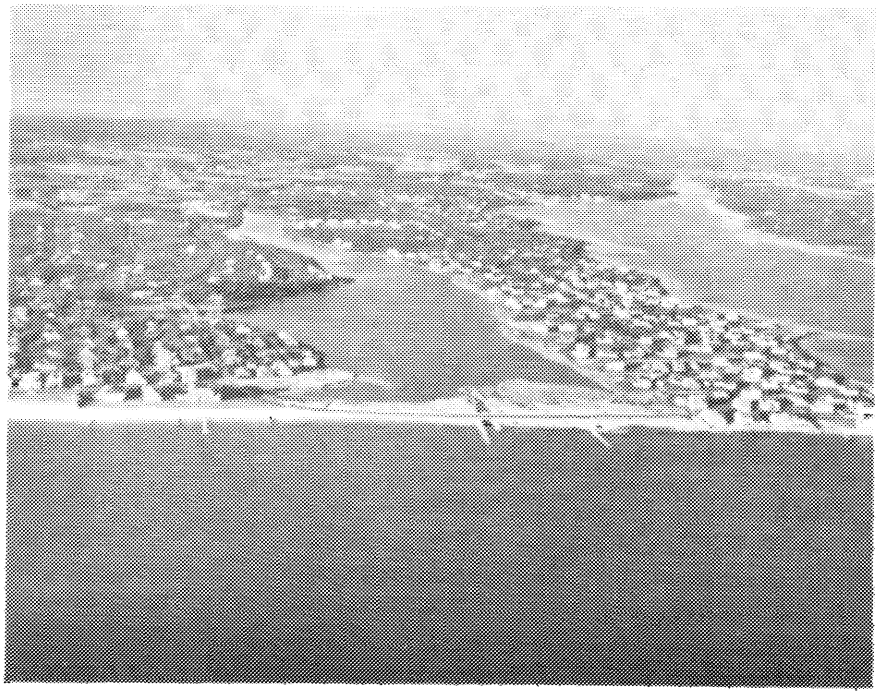


PHOTO 7 FALMOUTH HEIGHTS, LITTLE POND AND MARA VISTA - Nov 27, 1961

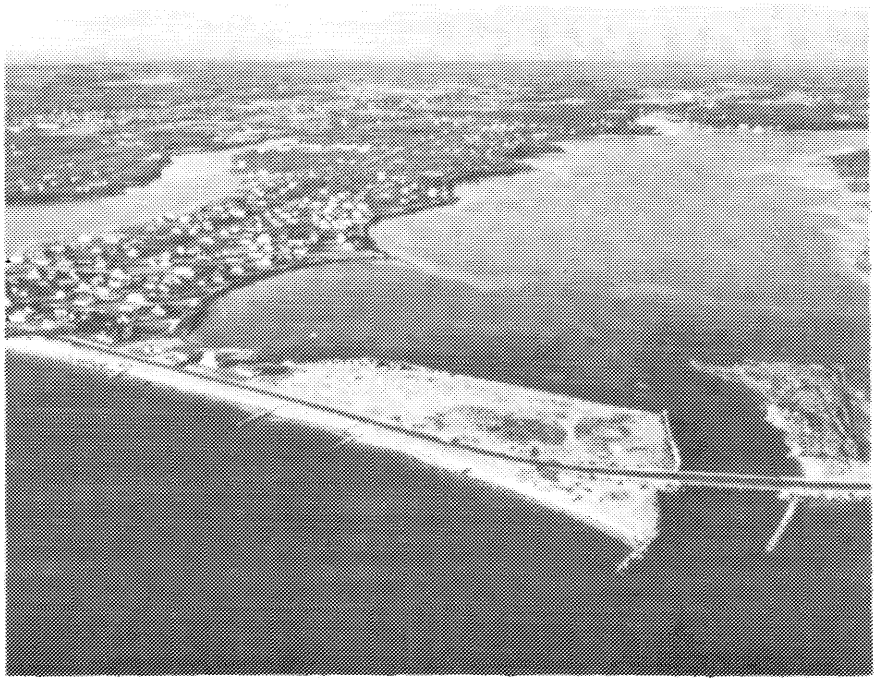


PHOTO 8 MARA VISTA AND GREAT POND INLET Nov 27, 1961

be reduced by seaward extension of the jetty. A plan of improvement and protection consisting of beach widening by fill placement, enlargement of the existing groin at the east limit of the fill and extension of the east jetty at the harbor entrance is shown on Plate 11.

28. Maintenance of the existing groins and replacement of sand fill losses, when needed, is a practicable method of maintaining the public bathing beach. The private shore at the east end of this area is being nourished by eastward drifting sand from the adjacent shore. Residences here are now adequately protected. Some overtopping of the low road fronting Little Pond occurs. Construction of a barrier to provide complete protection does not appear to be warranted. Raising the shore road or constructing a low wall along its landward side would provide partial protection which appears to be all that is warranted under present conditions of use.

29. Mara Vista. - The shore of Mara Vista extends approximately 2,400 feet from the Little Pond drainage culvert to Great Pond Inlet. At its ends, it consists of low baymouth bars fronting Little and Great Ponds. The shore is privately owned. Development consists of cottages and residences concentrated between the ponds on both the landward and seaward sides of a low road which closely borders the shore. The only buildings on the barrier bars are located on the landward side of the road fronting the west end of Great Pond. The beach between the high water line and the shore road varies in width from 50 to 90 feet fronting Little Pond and from 80 to 90 feet fronting Great Pond, increasing to 200 feet at the jetty at Great Pond Inlet. There is no beach fronting the development between the ponds which is protected by concrete walls, some with riprap revetment at their toes, and by concrete and stone groins. West of the development protective structures consist of the stone jetties at the culvert, a stone groin and the remains of concrete walls. To the east of the shore development, shore protection consists of rows of wood piles, dumped riprap, timber bulkheads and groins, low concrete walls and stone groins. The remains of protective works and abandoned concrete foundations along the barrier bars are mute evidence of former development. The barrier bars are composed mostly of sand varying from fine to coarse and some gravel. There are grassed sand dunes in the backshore east of the shore cottages. Some of the area landward of the shore road in the Great Pond section is the result of filling. Shoreline changes from 1845 to 1941 generally consisted of recession averaging about 1 to 1-1/2 feet per year. Since 1941, shoreline changes have consisted of a small amount of accretion at the west end and recession at the east end of the area with little change along most of the shore. The entire area is low and subject to

overtopping and wave attack during storms. Landward movement of beach material over the barrier bars can cover the shore road and damage it and any development on the bars. Due to the lack of a fronting beach, waves can break on and overtop protective structures fronting the shore cottages. The small amount of change in the shoreline position since 1941 indicates that the existing groins and walls have been successful in controlling recession of the shore. Complete protection of the area would require the construction of a high-fronting seawall or other barrier to prevent damaging wave attack, overtopping and landward movement of beach material. Such construction is not warranted by the limited amount of development which would benefit. In their present condition, the barrier bars are unsuitable for residential development due to their low elevation and consequent vulnerability to storm damages. Consideration was given to providing partial protection for this entire area by placement of sand fill to create a wider protective beach and construction of groins to retain or reduce losses of the fill. The beach could also be widened and nourished by placement of sand in a stockpile at the west end of the area and allowed to be distributed eastward along the shore by wave action. Extension of the west jetty at the Great Pond Inlet would be required to impound drifting sand and protect the inlet from shoaling. Use of the stockpile method of nourishment would result in higher rates of loss of the fill and require more frequent replenishment of the fill than if groins are used. Due to the steep foreshore slope and the proximity of comparatively deep water in the offshore area, the cost of the types of protection involving beach widening would probably be higher than warranted by prospective benefits. Partial protection for the shore road against overtopping and drifting sand san be provided by construction of a low wall along the seaward edge of the road where existing structures are not adequate for this purpose as shown on Plate 11. Maintenance of existing seawalls, groins and other structures should provide adequate protection for the shore residential development and for the sandy beaches under ordinary conditions but damages will occur during exceptionally severe storms.

30. Acapesket. - The Acapesket shore located between the jetties at the Great and Green Pond Inlets has a length of approximately 2,750 feet. Ownership is entirely private. Development consists of cottages on the landward side of the shore road along the westerly third of the area and on both sides in the central portion. The barrier bar fronting Green Pond along the easterly third of the shore is undeveloped. The beach is composed of medium and coarse sand and some gravel. Its width above high water varies irregularly. There is little or no beach along the west end where the shore road, closely bordering the shore, is protected by riprap, and a curved face precast concrete block wall and stone groins.

PHOTO 9 ACAPESKET, Nov 27, 1961 - Great Pond in background

PHOTO 10 DAVISVILLE AND BOURNES POND INLET - Nov 27, 1961

In the central portion, the sand beach varies from 0 to 80 feet, the greater width at the west sides of stone groins. In this area, cottages on the seaward side of the shore road are protected by stone groins, a stone mound, riprap and timber bulkheads. The barrier bar fronting Green Pond has a width of 200 to 300 feet and it is partially covered with grassed sand dunes. Shoreline changes along the entire Acapesket shore have been large over the period of record. Between 1845 and 1941, the shoreline receded at an average rate of 2 to 4 feet per year, the larger recession along the east half. From 1941 to 1961 the barrier bar fronting Green Pond and a segment of shore adjacent to the Great Pond Inlet receded up to about 200 feet more while changes along the rest of the area were comparatively small. Due to the narrowness of the beach fronting the shore road and the shore cottage development, the area is subject to damages from erosion, wave attack and overtopping. Some settlement of the precast concrete block wall which protects the shore road has occurred and the lawns fronting cottages are subject to erosion resulting from overtopping of the beach and existing protective structures. A large measure of protection is already afforded by existing protective works. Complete protection could be provided by construction of higher walls or barriers and armoring the shore with more riprap revetment. Due to the limited development which would benefit, provision of complete protection does not appear to be warranted. Partial protection can be provided by placement of a wider protective sand beach. The high rate of past shoreline recession indicates that beach fill material would be lost at a fairly rapid rate and that construction of groins to reduce fill losses would be necessary. A plan of protection involving placement of a wider protective sand beach and enlargement of existing groins to reduce fill losses has been developed in the event that prospective use or benefits should warrant such construction. The plan is shown on Plate 11. Maintenance of the existing system of protective works should generally provide the type of protection needed under present conditions of use.

31. Davisville. - The Davisville shore is located between the Green and Bournes Pond Inlets. It has a length of approximately 2,950 feet. Except for two town street ends, the area is privately owned. Development consists of summer residences which closely border the shore. The beach is composed mostly of medium sand and some coarse sand and gravel. At the west end, the area is an undeveloped barrier bar about 200 feet wide fronting Green Pond. The beach width above high water to the east along the residential development varies irregularly in front of lawns and protective structures from 0 up to 90 feet and it widens to 125 feet in front of a grass-covered dune and stone mound at the east end. The development is fronted by a continuous system of protective structures consisting of stone mounds, timber bulkheads and piles, riprap revetment and stone, timber and concrete groins.

During the period of record, from 1845 to 1941, the shoreline receded an average of 1 to 4 feet per year, with the largest shore loss at the west end. Since 1941, recession generally less than 25 feet, occurred along the west half and a seaward shoreline movement of 25 to 50 feet occurred along the east half of the shore. The reduction in the rate of shore recession and the accretion which has occurred since 1941 indicates that the existing protective structures have been successful in controlling erosion. Some erosion of the low bluff and lawns behind the beach occurs where the bluff has not been protected. Armoring the bluff by construction of stone mounds or placement of riprap revetment has provided effective protection in this area. The groins have been effective in reducing erosion. In the absence of natural sources of supply of beach building materials, these methods would not provide an adequate width of fronting protective sand beach. Unless such a supply is furnished, losses of the existing sand beach will gradually expose the area to more severe wave attack and require the construction of increasingly stronger protective works. A protective sand beach can be provided by direct placement of sand fill. Construction of groins would be necessary to reduce rapid losses of the fill. A plan of protection and improvement involving beach widening by fill placement, construction of a jetty at the Bournes Pond Inlet and construction of two new groins has been developed for possible future use and it is shown on Plate 12. Beach widening can also be effected by placing sand fill at the west end of the area and allowing it to nourish the shore by eastward drifting. Construction of a jetty would be required at the east end of the area to impound drifting sand and protect Bournes Pond Inlet from shoaling. This method of nourishment would be accompanied by a higher rate of loss of fill than the plan involving groin construction. Under present conditions of use and exposure, maintenance of existing or construction of additional seawalls, stone mounds, revetments or groins should provide adequate protection.

32. Menauhant. - The Menauhant shore, located between the Bournes Pond and Eel Pond Inlets consists of 1,850 feet of town-owned public bathing beach and 1,500 feet of privately-owned shore. The public beach is on a low sandy barrier bar fronting Bournes Pond. The road on the bar is protected by dumped riprap where it closely borders the shore. The fronting sandy beach varies irregularly in width from about 130 to 20 feet and it is protected by a series of 4 stone groins. There are no buildings on the bar. The private shore to the east is protected by 3 stone groins and a stone jetty at the Eel Pond Inlet, the two westerly structures fronting a residential development, the other two on an undeveloped sandy barrier bar at Eel Pond. There is a stone mound fronting the residential development with little or no width of sandy beach in front of the mound. The sandy barrier bar at Eel Pond is about 200

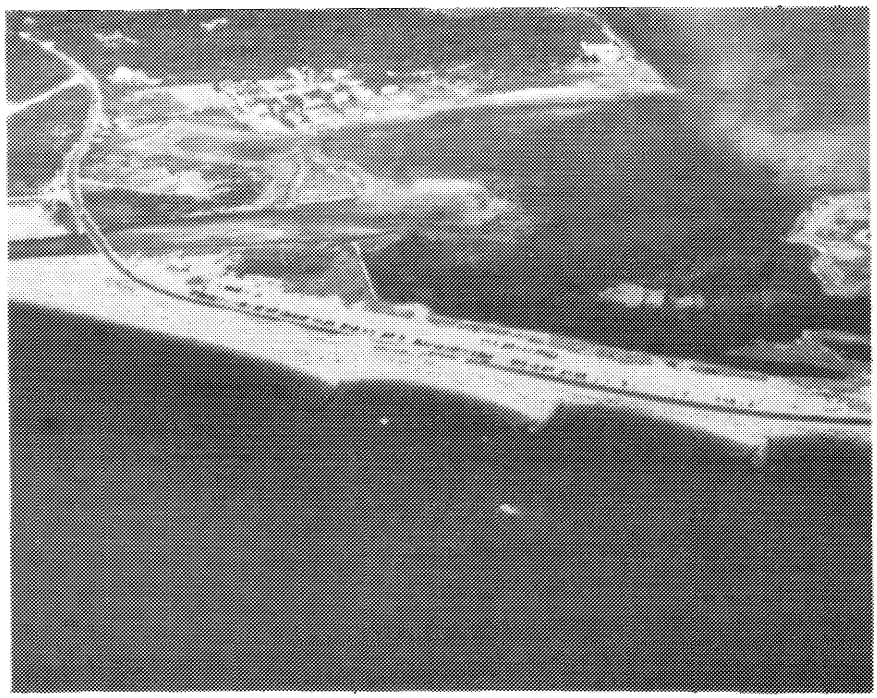


PHOTO 11 MENAUHANT BEACH, Aug 26, 1962 - Sunday attendance at the public bathing beach.

PHOTO 12 MENAUHANT, Nov 27, 1961. - Low shore between Bournes and Eel Ponds

feet wide. Except for one residence, all buildings are located on the landward side of the shore road. Between 1845 and 1942, the entire shore receded at an average rate of 1 to 3 feet per year. From 1942 to 1961, along the west half of the Menauhant shore, there was a seaward shoreline movement of 25 to 50 feet and during the same period the shore fronting Eel Pond receded a similar amount. The beach and barrier bars are low in elevation and subject to overtopping during storms accompanied by high tides. Damages occur along the residential development and the public shore area to the west where beach material moves landward over the shore road and onto lawns. The road is subject to damages from wave attack where the beach width is inadequate to provide protection. Some erosion of lawn areas also occurs. Consideration has been given by local interests to construction of a new bridge over Bournes Pond Inlet and relocation of the Menauhant shore road at a higher elevation along the landward side of the barrier bar. This would make it possible to provide complete protection for the road without interfering with or impairing the recreational use of the beach. Complete protection can be provided for the entire shore area by construction of high seawalls or other barriers seaward of the shore road and buildings but this is not warranted by the limited development which would benefit. Improvement and partial protection of the public shore and road and the private development can be provided by placement of sand fill to create a wider sand beach and construction of a low seawall along the seaward edge of the road. The history of recession of the shore indicates that groins would be required to reduce the rapid loss of the fill. A plan of protection and improvement involving beach widening along the private residential area and the narrow portion of the adjacent public bathing beach, the construction of a low seawall and the enlargement of three existing groins to reduce losses of the beach material has been developed for use in the event that future development or recreational use of the shore should warrant it. The plan is shown on Plate 12. The beach could also be widened and nourished by placing a stockpile of sand at the west end of the area and allowing the sand to drift eastward. Losses of fill would be higher using this method than with the fill plan involving groin construction. Maintenance of existing protective structures appears to be all that is warranted for present or prospective use of the barrier bar fronting Eel Pond.

33. Washburn Island. - The seaward end of Washburn Island is a sandy barrier bar extending about 5,800 feet from the entrance to Eel Pond to the entrance to Waquoit Bay. It is privately owned and completely undeveloped. There is a limited amount of development on that portion of the island extending northward from the beach. The bar increases in width from west to east from about 200 to about 1,000 feet and thence

decreases to about 400 feet at the Waquoit Bay Inlet. The shoreline from Menauhant to Washburn Island was continuous during 1845 and 1891. An opening into Eel Pond during the period 1938-1941 separated these two beaches, as at present, but a shoreline map shows a continuous shoreline here during 1942. The entire shoreline of Washburn Island receded at a rate of about 2 feet per year between 1845 and 1891. From 1891 to 1942 the shoreline receded about 200 feet at its west end and moved seaward about 300 feet at the Waquoit Bay entrance with the amount of change decreasing from the ends to an area of no change near the center. This pattern of shoreline movement continued from 1942 to 1961 resulting in a recession of about 500 feet more at the Eel Pond entrance and accretion of another 100 feet at the Waquoit Bay entrance. The accretion at the east end of the area is attributed to impounding of drifting beach material by construction of a jetty at the west side of the Waquoit Bay Inlet in 1937. The retreat of the west end of the barrier bar has left three stone groins which were built here, stranded offshore. The west end of the area is considered to be unsuitable for development at the present time due to the rapidity and magnitude of changes which have occurred. In the event that the wider, more stable east end of the island is developed, a safe escape road which would not be blocked or made unusable during storms or hurricanes should be provided. If future development requires it, this entire beach can be maintained by placing a stockpile of sand at its west end and allowing it to be moved eastward by wave action to nourish the shore. Beach material would be impounded by the west jetty at the Waquoit Bay entrance. Stabilization of the west end of the beach could be effected by construction of a jetty at the Eel Pond entrance west of the stockpile and a bulkhead or other barrier to landward movement from the jetty eastward behind the stockpile or behind the beach. Due to the lack of any development in the immediate area, there is no present need for the construction of protective works. The need for protective works for any future development can be elminated or greatly reduced by proper planning so as to locate buildings or other structures a safe distance landward of the shoreline.

PART V - ECONOMIC ANALYSIS

34. First Costs. - Detailed estimates of costs are included in Appendix I. First costs have been estimated for all projects for which detailed plans have been developed. Estimates are based on price levels prevailing during July 1962. Detailed plans have been developed for the locations tabulated below:

PHOTO 13 EEL POND INLET, Nov 27, 1961 - Three groins stranded offshore by retreat of west end of Washburn Island

PHOTO 14 WASHBURN ISLAND, Nov 27, 1961 - Extends westward from Waquoit Bay jettied inlet

Location	Shore Ownership	Paragraph Reference	Plate No.
Shore between Nobska Point and Falmouth Beach	Private	19	11
Falmouth Heights (West End)	Public & Private	20	11
Falmouth Heights (Central Portion)	Public	21	11
Mara Vista	Private	29	11
Acapesket	Private	30	11
Davisville	Public & Private	31	12
Menauhant	Public & Private	32	12

The estimated total costs or costs per linear foot for construction of the projects developed in detail are tabulated below:

Project	Work Items	Cost Per Linear Foot
Between Nobska Point and Falmouth Beach	Stone Mound and Slope Protection	$ 81.00
		Total Cost
Falmouth Heights (West End)	Groin and Jetty Enlargement and Beach Fill	$ 89,000
Falmouth Heights (Central Portion)	Stone Revetment and Slope Protection	48,000
Mara Vista	Concrete Wall	28,000
Acapesket	Enlargement of 4 Groins and Beach Fill	278,000
Davisville	Construction of Jetty, 2 Groins and Beach Fill	207,000
Menauhant	Enlargement of 3 Groins, Beach Fill and Concrete Wall	195,000

35. Annual Charges. - All estimated annual charges have been computed as non-Federal annual charges. An interest rate of 3.5% has been used. A useful life of 50 years has been assumed in determining amortization charges. Maintenance estimates for beach fills are generally based on the maximum rates of loss determined from past shore recession. A shore recession of 2 feet per year was assumed for the fill area at Falmouth Heights. It has been assumed that the proposed groin and jetty construction will reduce the rate of loss of beach fill by 50 percent. Estimated annual costs, computed in detail in Appendix I, are as follows:

Location	Interest	Amortization	Maintenance	Total Per Linear Foot
Between Nobska Point and Falmouth Beach	$ 2.80	0.60	0.60	$ 4.00
				Total
Falmouth Heights (West End)	3,100	700	2,100	5,900
Falmouth Heights (Central Portion)	1,700	370	510	2,580
Mara Vista	1,000	200	300	1,500
Acapesket	9,700	2,100	3,800	15,600
Davisville	7,250	1,580	2,770	11,600
Menauhant	6,800	1,400	3,300	11,500

36. Benefits. - Benefits have not been evaluated since economic justification was apparently lacking or the benefits are not of a type to make the projects eligible for Federal aid under existing Federal policy. The protection between Nobska Point and Falmouth Beach is for private property and the benefits to be derived are wholly private. The projects for the west end of Falmouth Heights and for Menauhant are for shores which are partly public and partly private. The projects would enlarge the beaches for recreational use and would result in minor public benefits from protection of the shore roads. Lengthening the Falmouth Inner Harbor East Jetty would reduce harbor shoaling. The beach areas involved are adequate for present recreational use. No recreational benefits can be evaluated for present or prospective use based on available information. The central portion of Falmouth Heights is publicly owned. Public benefits from prevention of erosion of the bluff would have a small monetary value which would not be sufficient for economic

justification. The Acapesket shore is all privately owned. Benefits would be principally private, consisting of prevention of erosion and storm damages to the private residential development. Some minor public benefits would result from protection of the shore road but these benefits would have only a small monetary value. The Davisville shore is principally private and benefits would be almost entirely private, consisting of prevention of erosion and storm damages to the private residential development.

37. Apportionment of Costs. - Public Law 826, 84th Congress, established a policy of Federal aid for restoration and protection against erosion of the shores of the United States, its territories and possessions. Private shores are eligible for Federal assistance if there is a benefit such as that arising from public use or from protection of nearby public property, or if the benefits to those shores are incidental to the project. The benefits which could be evaluated for protection or improvement of public shores are insufficient for economic justification of the projects. Protection or improvement of private shores would not result in significant public benefits. All estimated costs, therefore, are apportioned as non-Federal costs.

38. Coordination With Other Agencies. - Coordination has been maintained with the cooperating agency, the Division of Waterways of the Massachusetts Department of Public Works and with officials of the town of Falmouth. They furnished information and data which were used in the conduct of the study. The plans of protection were discussed with both during the progress of the study and their comments were requested upon completion of this report. The Massachusetts Water Resources Commission was also informed concerning the report recommendations. The Barnstable County Health Department furnished information concerning bacterial tests of shore waters. The United States Coast and Geodetic Survey furnished maps, aerial photographs and data on tidal observations. The views of the Federal and State fish and wildlife agencies concerning aspects of the study pertaining to their interests were requested.

39. Comments of Local Interests and Other Agencies. - The Division of Waterways of the Massachusetts Department of Public Works reviewed the findings of the study and concurred in its conclusions. It stated that the results of the study will be extremely useful in the future for use by the town and the Commonwealth for planning projects within the areas studied. The Massachusetts Division of Fisheries and Game, based on its review of the study findings, advised that:

a. The proposed stone mounds, revetment and low walls between Nobska Point and Falmouth Beach, at Falmouth Heights

Bluffs and at Mara Vista would have no apparent adverse effect on the fish and wildlife resources of the area nor do they afford opportunity for their enhancement.

b. In the remaining proposed project areas there is opportunity for enhancement by providing additional access vantages for land-based marine sports fishermen. This could be accomplished by constructing stone groins and jetties so as to facilitate public fishing therefrom by minimizing voids and irregularities to permit persons to walk on the structures.

c. Emphasis should be placed on construction of the following structures in closest proximity to the salt pond openings where desirable species of fish concentrate as a result of tidal flow:

The Falmouth Harbor east jetty
The west and east groins at Acapesket
The jetty at Davisville adjacent to the Bournes Pond opening
The east groin at Menauhant

d. Further opportunities for enhancement consisting of habitat improvement could be realized by obtaining fill for beaches from deepening of existing channels within adjacent salt ponds. This would provide for a better exchange of tidal waters between Vineyard Sound and the salt ponds and a subsequent improvement in sport fishing conditions.

e. The removal of beach fill materials from other than existing channels in salt ponds could be detrimental to marine aquatic populations. All sport fishes are either directly or indirectly dependent upon the natural, undisturbed estuarine environment for their existence. In fact, the winter flounder, the most important species to the greatest number of marine sport fishermen, would definitely be adversely affected by the removal and/or change of this habitat.

f. If dredging for fill is undertaken in existing channels of salt ponds for beach fill, it is recommended that such not be conducted during the period from January 1 to April 1. Inasmuch as winter flounder utilize the salt ponds for spawning, dredging and resultant siltation during this period could adversely affect spawning success.

The United States Fish and Wildlife Service furnished a conservation and development report prepared in cooperation with the Massachusetts Division of Marine Fisheries and Division of Fisheries and Game. This report in its entirety is included as Appendix L. Principal comments on the proposed plans of protection were as follows:

a. The proposed works would be situated in areas of biological significance. Shellfish in the salt water ponds support a commercial and recreational shell fishery of considerable significance. Finfish resources support a highly valued sport fishery. The evaluated benefits estimated from sport fishing from groins and jetties which would be affected by the proposed projects are $36,000 annually in their existing condition, $94,500 with the proposed projects and $127,500 if the proposed projects were modified by provision of parking areas and construction of structures to facilitate fishermen use.

b. Dredging offshore or from inland borrow pits to obtain beach fill and construction of stone mounds or stone revetments would not have any significant effect upon fish and wildlife resources. Dredging from the ponds behind the beaches would be damaging to the resources if fill were removed from certain areas. Dredging of the marshland along the southwestern and western shores of Green Pond would destroy habitat of special value to shorebirds. Recommended dredging areas and shellfish habitat are shown on plans of Falmouth Inner Harbor, Bournes Pond and Great Pond. Dredging in indicated areas would enhance habitat conditions for finfish and shellfish. The town should be notified 90 days in advance of dredging in Falmouth Inner Harbor or Great Pond to permit removal of shellfish and dredging should be done between October 1 and January 1 in any pond of indicated significance to shellfish or waterfowl to minimize siltation damages. Dredging should be done in such manner that the seaward end of each channel be dredged through the offshore shoals at the pond entrance to provide a continuous channel and unimpeded interchange of waters between the ponds and the sound. Marsh habitat or marshland should not be used as spoil areas, or filled to provide parking areas, if convenient parking facilities can be provided elsewhere. Parking areas should be constructed on the land side of the road.

c. Due to access possibilities and use, potential increase in sport fishery benefits would be most applicable to the proposed construction or enlargement of the following groins or jetties:

Falmouth Harbor east jetty
Groin 1200 feet east of Falmouth Harbor
Groin 1000 feet west of Green Pond
Two groins at Davisville
Bournes Pond west jetty
Three groins at Menauhant.

PART VI - CONCLUSIONS AND RECOMMENDATIONS

40. Conclusions. - The Division Engineer concludes that the following are practicable plans for protection and improvement of shore areas which merit consideration, all as shown on Plates 11-12.

a. Between Nobska Point and Falmouth Beach. - Construct stone mounds or stone revetment wherever needed for bluff protection.

b. Between Falmouth Inner Harbor and Bluffs at Falmouth Heights. - Widen 1,000 feet of beach by direct placement of sand fill, lengthen Falmouth Harbor east jetty to 250-foot length, enlarge and lengthen existing groin to 250-foot length.

c. Falmouth Heights Bluffs. - Place additional riprap revetment along the toe of approximately 1,450 feet of wall, place stone revetment on approximately 750 feet of slope above the wall and control surface runoff wherever needed.

d. Mara Vista. - Construct low walls, approximately 1,900 feet long along the seaward side of the shore road.

e. Acapesket. - Widen 1,300 feet of beach by direct placement of sand fill, enlarge and lengthen four (4) existing groins to 345 to 510-foot lengths.

f. Davisville. - Widen 1,500 feet of beach by direct placement of sand fill, construct a jetty 530 feet long and two groins 340 and 510 feet long.

g. Menauhant. - Widen 1,600 feet of beach by direct placement of sand fill, construct a low wall 1,500 feet long, enlarge and lengthen three (3) existing groins to 240 to 280-foot lengths.

41. The tip of Nobska Point is adequately protected by the existing stone mound and stone slope revetment. Maintenance of these protective works is all that is needed here.

42. Suitable protection for the low shore road east of the tip of Nobska Point can be provided by maintenance of the existing riprap revetment. Protection against overtopping, if desired, can be provided by reconstructing the road at a higher elevation and placing riprap revetment along the road embankment.

43. The shore between Nobska Point and Falmouth Inner Harbor is, in general, suitably protected against erosion and shore recession by existing protective works. Maintenance of existing structures or construction of additional similar structures is all that is needed at the present time. If it is desired or becomes necessary in the future, the existing beaches in this area can be improved, maintained or restored by placement of sand fill directly on the beaches or in stockpiles to be distributed by wave action.

44. The use of stockpiles of sand placed at the shore to be distributed by wave action is a suitable method for maintaining and

improving the sand beaches at Falmouth Heights, Washburn Island and from Nobska Point to and including Falmouth Beach. Direct placement of sand fill along the beaches is probably more suitable than the stockpile method for maintaining beaches at Acapesket, Davisville, Menauhant and the shore between Falmouth Beach and Falmouth Inner Harbor.

45. Barrier bars throughout the study area are generally unsuitable for residential development due to their low elevation and vulnerability to overtopping and damages during severe storms or hurricanes.

46. Complete protection of low shore areas by high seawalls or other barriers to prevent overtopping and consequent damages during severe storms or hurricanes is not warranted by the limited developments which would benefit.

47. Reconstruction or relocation of low shore roads at higher elevations landward of their present locations is a suitable means for protecting the roads and the developments landward of them.

48. In the event that the public shore at the west end of Falmouth Beach or the shore at Washburn Island are developed, buildings or other structures should be located at a high enough elevation or far enough landward to minimize damaging wave attack which could occur during severe storms or hurricanes.

49. Due to the adequacy of public beach areas for present recreational use, the lack of information to indicate the need for additional area for prospective use, the small value of benefits to be derived from protecting public roads and public lands or the private ownership and consequent private benefits to be derived from protecting private property, the public interest, as required by Public Law 826, 84th Congress, is insufficient to warrant Federal participation in the cost of the projects considered.

50. Additional information on recommended or alternative projects called for by Resolution 148, 85th Congress, 1st Session, adopted 28 January 1958 is contained in Appendix J to this report.

51. Recommendations. - It is recommended that no project be adopted by the United States at this time for the protection or improvement of the shores of Falmouth, Massachusetts. It is further recommended that protective measures which may be undertaken by local interests based upon their determination of

economic justification be accomplished in accordance with plans and methods considered in this report.

P.C. HYZER
Colonel, Corps of Engineers
Division Engineer

24 Incls
12 Appendices
12 Plates

APPENDIX A

DESCRIPTION AND COMPOSITION OF BEACHES

1. General. - Detailed descriptive data concerning the shore line was obtained by field inspections. Descriptions of the shore divided generally into areas in accordance with the physical character of shore features or the limits of public ownership are included in the subparagraphs below in geographic sequence from Nobska Point to Waquoit Bay. Surface samples of beach and nearshore material were obtained in the coastal area on selected profiles. Results of analyses of these samples are included in Appendix C. Locations of profiles are shown on Plates 2-4, inclusive. Ground and aerial photographs were taken of the entire shore. Selected photographs are included in the text of the report.

a. Nobska Point

(1) Location: West limit of the study area.

(2) Shore Length: 1,250 feet.

(3) Beach Width Above H. W.: No sand beach. Water line at sloping face of protective stone mound.

(4) Ownership: Town of Falmouth.

(5) Public Facilities: None.

(6) Composition of Shore: Stone faced glacial till and boulder headland.

(7) Protective Structures: Stone mound around toe of headland and stone revetment on slope above the mound.

(8) Character of Development: Town road borders top of bluff. United States Coast Guard Station on land side of shore road.

b. Nobska Point

(1) Location: East side of point north of Coast Guard Station.

(2) Shore Length: 950 feet.

(3) Beach Width Above H. W.: No sand beach along southerly 300 feet of shore. Sandy beach width of about 50 feet increasing northward to about 100 feet along rest of shore.

(4) Ownership: Private.

(5) Public Facilities: None

(6) Composition of Shore: Dumped riprap along southerly 300 feet of shore. Fine to medium sand beach with some gravel north of the riprap. Low grass covered sand dunes in backshore of north end of beach.

(7) Protective Structures: Dumped riprap close to shore road along southerly 300 feet. Three stone groins, rough condition.

(8) Character of Development: Residential on land side of shore road.

c. Between Nobska Point and Falmouth Beach

(1) Location: Northeast of and adjacent to Nobska Point along the residential development located seaward of Beach Road.

(2) Shore Length: 4,500 feet.

(3) Beach Width Above H. W.: Varies from about 30 feet to 125 feet in front of existing structures, bluffs or dunes. Generally wider at west side of groins.

(4) Ownership: Private.

(5) Public Facilities: None

(6) Composition of Shore: Medium sand beach berm at southwest end changing to medium and coarse sand, then coarse sand and then coarse sand and gravel at the northeast end. Some gravel on all the sand beach and scattered boulders offshore. The foreshore generally covered with gravel.

(7) Protective Structures: A series of stone groins (10), three timber piers and a series of disconnected protective works consisting of a stone wall fronted with mortared stone revetment, a timber bulkhead fronted with dumped riprap, a low stone wall and varying lengths of sloping stone revetment along the toes of bluffs.

(8) Character of Development: Residences located well behind the shore.

d. Between Nobska Point and Falmouth Beach

(1) Location: 1,800 to 3,200 feet west of Oyster Pond.

(2) Shore Length: 1,400 feet.

(3) Beach Width Above H. W.: 50-60 feet.

(4) Ownership: Private.

(5) Public Facilities: None

(6) Composition of Shore: Medium sand, gravel and cobbles. Blanket of gravel and cobbles in foreshore. Beach berm largely covered with gravel, with sand under the gravel.

(7) Protective Structures: Stone groin at west limit. Timber pier near center of area.

(8) Character of Development: Railroad line behind the beach. Residences behind the railroad line.

e. Falmouth Beach. (West End)

(1) Location: 400 to 1,800 feet west of Oyster Pond.

(2) Shore Length: 1,400 feet.

(3) Beach Width Above H. W.: About 50 feet.

(4) Ownership: Town of Falmouth.

(5) Public Facilities: None

(6) Composition of Shore: Gravel covered beach at west end with increasing amounts of sand on the surface to the east. Fine to medium sand beach at east end above high water with fine gravel deposit below high water.

(7) Protective Structures: Dumped riprap fronting a portion of the railroad.

(8) Character of Development: Residences landward of the railroad and ponds.

f. Falmouth Beach (Central Portion)

(1) Location: Fronting Oyster and Salt Ponds and Surf Drive.

(2) Shore Length: 4,850 feet.

(3) Beach Width Above H. W.: 70 feet at west end in front of railroad, widens to about 140 feet at intersection of railroad and Surf Drive and then narrows to 20-30 feet in front of riprap bordering Surf Drive at Oyster Pond. Varies irregularly between 100 and 20 feet along groin system from Oyster Pond and the jettied outlet to Salt Pond, then increases in width from 60 to 160 feet and then decreases to about 70 feet along the cottage development from the Salt Pond outlet to the east end of the area.

(4) Ownership: Private except for 50 feet at the jettied outlet to Salt Pond which belongs to the Town of Falmouth.

(5) Public Facilities: None

(6) Composition of Shore: Mostly a medium and coarse sand beach covered with a scattered layer of fine gravel. The gravel deposits diminish and cease at the east end of the area. Some fine sand adjacent to the railroad at the west end and grass covered dunes in the backshore in the cottage area. Considerable gravel in the foreshore along the westerly portions of the beach.

(7) Protective Structures: Dumped riprap or a low concrete seawall along portions of the seaward edge of Surf Drive. A system of seven (7) stone groins west of the Salt Pond outlet. Two stone jetties at the Salt Pond outlet and two timber piers at the cottage area to the east.

(8) Character of Development: Railroad line on the beach at west end and cottages on the beach on the seaward side of Surf Drive to the east. Residential development landward of Surf Drive and the ponds.

g. Falmouth Beach (Eastern Portion)

(1) Location: Between Salt Pond and Shore Avenue

(2) Shore Length: 2,350 feet.

(3) Beach Width Above H. W.: Increases from about 70 feet at west end to about 160 feet at the bathhouse.

(4) Ownership: Town of Falmouth.

(5) Public Facilities: Parking areas at land side of Surf Drive at west end. Bathhouse and parking area on the beach at the east end. Lifeguard stations.

(6) Composition of Shore: Coarse sand at the west end changing to medium sand at the east end. Some grass covered sand dunes about five feet high in the backshore.

(7) Protective Structures: Two stone jetties inclosing a culvert draining Sliders Pond. Curved jetties or breakwaters near the east end fronting the parking lot which is protected by a low concrete curb, mortared stone revetment and a concrete capped steel sheet pile bulkhead.

(8) Character of Development: A public bathing beach. Residences on the landward side of Surf Drive.

h. Between Falmouth Beach and Falmouth Inner Harbor

(1) Location: From Shore Avenue to the Falmouth Harbor West Jetty.

(2) Shore Length: 2,400 feet.

(3) Beach Width Above H. W.: No sand beach fronting revetment along west end. Narrow sand beach up to about 40 feet in width in center of area increasing eastward to about 150 feet at the Falmouth Harbor jetty.

(4) Ownership: Private.

(5) Public Facilities: None

(6) Composition of Shore: Sand beach gets finer to east changing from coarse to medium sand. High grass covered sand dune at east end at jetty.

(7) Protective Structures: From west to east protective structures consist of a sloping faced riprap mound; remains of a concrete wall fronted by dumped riprap; a stone groin; short timber and stone groins fronting a mortared and dry stone mound; a concrete wall with short spur concrete groins; a curved and then vertical faced concrete wall fronted by a stone groin; a row of boulders; walls of concrete, stone, concrete and stone. There is a mortared stone jetty at the east end at the Falmouth Harbor entrance.

(8) Character of Development: Residences, generally well behind the shore.

i. Falmouth Heights (West End)

(1) Location: East of and adjacent to Falmouth Harbor entrance.

(2) Shore Length: 1,150 feet.

(3) Beach Width Above H. W.: 70 to 80 feet.

(4) Ownership: 150 feet adjacent to the Falmouth Harbor jetty belongs to Town of Falmouth. Remainder private.

(5) Public Facilities: Public parking and boat landing area at Falmouth Harbor entrance.

(6) Composition of Shore: Medium sand and small amount of gravel.

(7) Protective Structures: Stone jetty at Falmouth Harbor entrance. Mortared stone revetment in front of motel. Dumped riprap along the edge of the shore road.

(8) Character of Development: Public and private bathing beach. Motel on the beach. Residential landward of the shore road.

j. Falmouth Heights Public Beach (West Part)

(1) Location: West of and adjacent to the Casino.

(2) Shore Length: 1,800 feet.

(3) Beach Width Above H. W.: Little or no sand beach fronting most of the area. A sand beach widens eastward at the east end of the area to about 165 feet in the vicinity of the groin near the Casino.

(4) Ownership: Town of Falmouth.

(5) Public Facilities: Lifeguard station east end.

(6) Composition of Shore: Boulders and riprap along most of shore. Medium sand beach with small amount of gravel along easterly end.

(7) Protective Structures: Stone groin near each end. A concrete wall fronted with dumped riprap at toe of bluff along most of the area. Stone slope revetment above the wall along the eastern portion.

(8) Character of Development: Residences, inns and summer hotels landward of the shore road.

k. Falmouth Heights Public Beach (East Part)

(1) Location: East of and including the Casino.

(2) Shore Length: 1,650 feet.

(3) Beach Width Above H. W.: 120 feet at the west end, 165 feet in the middle and about 90 feet at the east end.

(4) Ownership: About 230' at the Casino is private. The remainder belongs to the Town of Falmouth.

(5) Public Facilities: Lifeguard platforms, concrete ramps and steps from sea wall down to beach and a walk and park benches behind the wall.

(6) Composition of Shore: Fine, medium and coarse sand and gravel at the west end. Fine, medium and coarse sand at the east end.

(7) Protective Structures: Riprap around the Casino and a concrete sea wall east of the riprap fronting a park area behind the sand beach. Three stone groins along the beach.

(8) Character of Development: A public bathing beach with a theatre at the west end and residences and inns landward of the shore road.

l. Falmouth Heights (East End)

(1) Location: From the east end of the public beach to the culvert at the Little Pond inlet.

(2) Shore Length: 850 feet.

(3) Beach Width Above H. W.: Decreases eastward from about 90 to 75 feet fronting residences and to 40 feet along the road fronting Little Pond. Widens to 60 feet at the west side of the Little Pond culvert.

(4) Ownership: Private, except for jettied culvert opening at Little Pond which belongs to the Town of Falmouth.

(5) Public Facilities: None

(6) Composition of Shore: Medium and coarse sand and a small amount of gravel.

(7) Protective Structures: A concrete wall, three (3) stone groins and a timber pier along the residential development. A concrete wall and/or riprap revetment along the road fronting Little Pond. Stone jetties flanking Little Pond culvert.

(8) Character of Development: Residential along west half. Shore road on barrier bar along east half.

m. Mara Vista

(1) Location: Between Little Pond culvert and Great Pond Inlet.

(2) Shore Length: 2,400 feet.

(3) Beach Width Above H. W.: Increases eastward from about 50 to 90 feet in front of shore road on Little Pond barrier beach. None fronting residences and cottages located on the beach east of Little Pond and 80 to 90 feet east of these residences increasing to 200 feet at the Great Pond jetty.

(4) Ownership: Private.

(5) Public Facilities: None

(6) Composition of Shore: Medium sand at the west end with some gravel near the culvert. Medium and coarse sand and increasing quantities of gravel to the east. Grassed sand dunes in the backshore east of the shore residences.

(7) Protective Structures: Stone jetties at each end. A stone groin and the remains of concrete walls west of the shore cottages. Concrete walls with fronting stone revetment, timber, concrete and stone groins in front of shore cottages. Row of wood piles, dumped riprap, timber bulkheads and groins, low concrete walls and stone groins east of the shore cottages.

(8) Character of Development: Cottages and residences on and behind the beach in the central portion of the area. None on the barrier bars fronting the ponds at the ends of the area.

n. Acapesket

(1) Location: Between Great Pond and Green Pond Inlets.

(2) Shore Length: 2,750 feet.

(3) Beach Width Above H. W.: Little or none fronting riprap revetment from the Great Pond jetty to the 2nd groin to the east; thence two sandy pockets 30 to 75 feet wide, the greater width at the west side of groins; thence a stone mound at the water edge and a sand beach widening to about 80 feet at the groin at the east end of the shore residences; thence a barrier bar 200-300 feet wide fronting Green Pond west of the inlet jetty.

(4) Ownership: Private.

(5) Public Facilities: None

(6) Composition of Shore: Sandy beach areas consist of medium sand at the west end and medium and coarse sand in the central and eastern portion with small amounts of gravel in the entire area. The barrier bar fronting Green Pond is grass covered.

(7) Protective Structures: Stone jetties at each end and five (5) stone groins in between. Dumped riprap and precast curved face concrete block wall fronted by riprap revetment along edge of road along the westerly third of the area. A stone mound, dumped riprap with a row of wood piles and a timber bulkhead fronting shore residences in the central part of the area.

(8) Character of Development: Cottages on the landward side of the shore road along the westerly third of the area and on both sides of the shore road in the central portion. No development on the barrier bar fronting Green Pond.

o. Davisville

(1) Location: Between Green Pond and Bournes Pond Inlets.

(2) Shore Length: 2,950 feet.

(3) Beach Width Above H. W.: A barrier bar about 200 feet wide fronting Green Pond; thence beach width varies irregularly to the east in front of protective structures and lawns at shore cottages from about 0 to 90 feet. At the east end the beach is 90 to 125 feet wide in front of a grass covered sand dune and stone mound.

(4) Ownership: Private except for two town owned street ends at Davis Neck Road and Davisville Road.

(5) Public Facilities: None

(6) Composition of Shore: Generally medium sand. Coarse and medium sand at each end with some gravel at the east end.

(7) Protective Structures: Stone jetty and timber bulkhead at Green Pond Inlet. Various types of structures in front of the shore cottages consisting of stone mounds, timber bulkheads, riprap revetment, timber piles and a series of groins of stone, timber and concrete.

(8) Character of Development: Summer residences closely bordering the shore.

p. Menauhant (West Portion)

(1) Location: East of and adjacent to Bournes Pond Inlet.

(2) Shore Length: 1,850 feet.

(3) Beach Width Above H. W.: About 130 feet to shore road at the west end decreasing to about 80 feet at the second groin to the east, to 20 feet fronting riprap between the second and third groins, 60 feet at the third groin and 110 feet at the west side of the groin at the east end.

(4) Ownership: Town of Falmouth.

(5) Public Facilities: Parking area and lifeguard stand.

(6) Composition of Shore: Mostly medium sand with some coarse sand at both ends. Grass covered sand dunes behind a small part of the wider westerly end of the beach.

(7) Protective Structures: Four (4) stone groins. Remains of timber bulkhead and groins, dumped riprap along the edge of some of the road and two short flanked timber groins.

(8) Character of Development: A public bathing beach. No buildings.

q. Menauhant (East Portion)

(1) Location: Between the town bathing beach and the Eel Pond Inlet.

(2) Shore Length: 1,500 feet.

(3) Beach Width Above H. W.: About 110 feet at the west end. No sand beach in front of protective structures along the shore along the residential development and a sandy beach and barrier bar about 200 feet wide at the east end of the area at Eel Pond.

(4) Ownership: Private.

(5) Public Facilities: None

(6) Composition of Shore: Medium and coarse sand with material coarser in the tidal zone.

(7) Protective Structures: A stone mound alongshore in the vicinity of the high water line and two fronting stone groins along the residential development. A stone groin on the barrier bar to the east and a stone jetty at the Eel Pond Inlet.

(8) Character of Development: Residential on and behind the shore between Bournes and Eel Pond.

r. Washburn Island

(1) Location: Between Eel Pond and Waquoit Bay Inlets.

(2) Shore Length: 5,800 feet.

(3) Beach Width Above H. W.: A sandy barrier bar varying from 200 to 1,000 feet.

(4) Ownership: Private.

(5) Public Facilities: None

(6) Composition of Shore: A sandy barrier bar.

(7) Protective Structures: Three flanked stone groins 200 to 400 feet offshore opposite the west end of the island. Stone jetties at the Waquoit Bay Inlet.

(8) Character of Development: An undeveloped shore.

APPENDIX B

GEOMORPHOLOGY

1. General Geology of Western Cape Cod. - Bedrock is 100 feet or more below sea level south of the Cape Cod Canal. Two bouldery earth ridges (moraines) intersect at the canal, marking a long stand of the ice front prior to glacial retreat and ice stagnation. They represent glacially plowed erosional debris deposited at the glacier's snout. The moraines, the Buzzard Bay moraine on the southwest and the Sandwich moraine on the east are classified in this area as "interlobate", each representing materials carried by a different lobe of a general glacial margin. They carry many boulders and consist partly of glacial till, hence are fairly resistant to erosion. Topographically they are pronounced high hills, rough country with a dense cover of brush, scrub pine and a few deciduous trees.

2. The area between the two moraines comprises the bulk of the inner arm of Cape Cod. Known as the "Mashpee pitted plain," it has been described by Mather, et al , as "a slightly dissected, subaerially constructed alluvial fan with its apex at an elevation of 220 feet close to the place of overlap of one moraine upon the other, and its surface sloping gently to the curving shoreline, 10 to 14 miles distant toward the south and southeast". The plain consists largely of stratified sands, grading surficially from coarser near the apex to finer at the lower end. Topographically it appears nearly flat, interrupted only by "kettle holes", depressions left by melting of ice blocks bur ied in the sand, and erosion furrows, quite striking in their regularity and effect on the shoreline. The moraines, pitted plain and kettle holes (appearing as numerous ponds) are shown on Figure B-1.

3. Coastal Geology of the Falmouth Area. - Most of the study area is situated on the sea margin of the plain, about 12 miles south of its apex. The west end of the area at Nobska Point, however, is a prominent headland formed where the Buzzards Bay moraine extends seaward, becoming the Elizabeth Islands chain and reappearing along the southwest coast of Rhode Island, Fishers Island and parts of Long Island, New York.

4. The relationships between the shoreline and geological features are simple and extremely clear. The till and boulders of the moraine, coupled with its high relief, present a far greater resistance to erosion than the sandy plain, hence the moraine stands out

as a prominent headland and protecting bulwark for the area to the east. Succonnessett Point, two miles east of the study area, is anomalous in that it stands out from the plain, like an island, and is a sandy hill with a till core inland. A winged headland, it serves as a giant groin and bulwark. Its erosion would cause all of the shore to its west (except possibly for a small area immediately east of Nobska Point) gradually to retreat. A series of alternating cycles can be envisaged whereby the headlands retreat and eroded material nourishes intervening beaches, beaches are eroded because of lack of headland protection and the process repeats itself.

5. The beaches are mostly low, thin baymouth bars cutting off flooded erosion furrows with materials eroded from the ends of prongs between the furrows. Several of the ponds and the largest inlet, Waquoit Bay, consist of flooded kettle holes.

6. Nobska Point to Falmouth Harbor. - The shoreline east of Nobska Point for about 1¼ miles is morainal. From that point eastward to Falmouth Harbor entrance, the shoreline consists of marine and shallow marsh deposits and represents a continuous chain of baymouth bars derived from erosion of the moraine in the Woods Hole vicinity and perhaps to a lesser extent from the erosion of the fringe of the nearby flat Mashpee plain to the north and east. The embayment forming Oyster Pond is a flooded late glacial or post glacial depression in the moraine, or possibly a depression resulting from the melting of a mass of ice embedded in the moraine. Salt Pond and marshy tracts behind the bar to the east, nearly to Falmouth Harbor entrance, merely represent former ocean water cut off by the development of the bar owing to drift processes supplying sand eroded from the moraine to the West. Sand accumulations against groins do not seem to favor one direction of drift over the other west of the Falmouth town beach along Surf Drive. East of this town beach accumulation at groins is from the west.

7. Falmouth Harbor to Waquoit Bay. - The shoreline from Falmouth Harbor to Waquoit Bay, except for a fairly small but prominent till hill comprising Falmouth Heights, consists of five low and narrow baymouth bars fronting ponded erosional furrows. The intervening prongs between furrows have been terminated by erosion causing the entire shoreline to appear fairly straight, except at the mouth to Waquoit Bay where the tidal inlet to the bay is situated in the center of a large sand cusp. The bars are extremely vulnerable to storm damages because of their low relief and small girth. Most of the ponds are connected to the sound by tidal inlets. The entire bar fronting Eel Pond was breached and pushed back in the recent past, leaving a series of groins on the seaward side of the bar standing well out into the

ocean and causing the low prong between the east branch of Eel Pond furrow and the series of kettle holes forming Waquoit Bay to become an island. The extreme instability of this locality owes to the close proximity of the kettle hole to the furrow. The area will probably be subjected to more radical changes in the near future, the situation being aggravated by an inadequate supply of incoming sand while storm waves make materials available for drifting to the east.

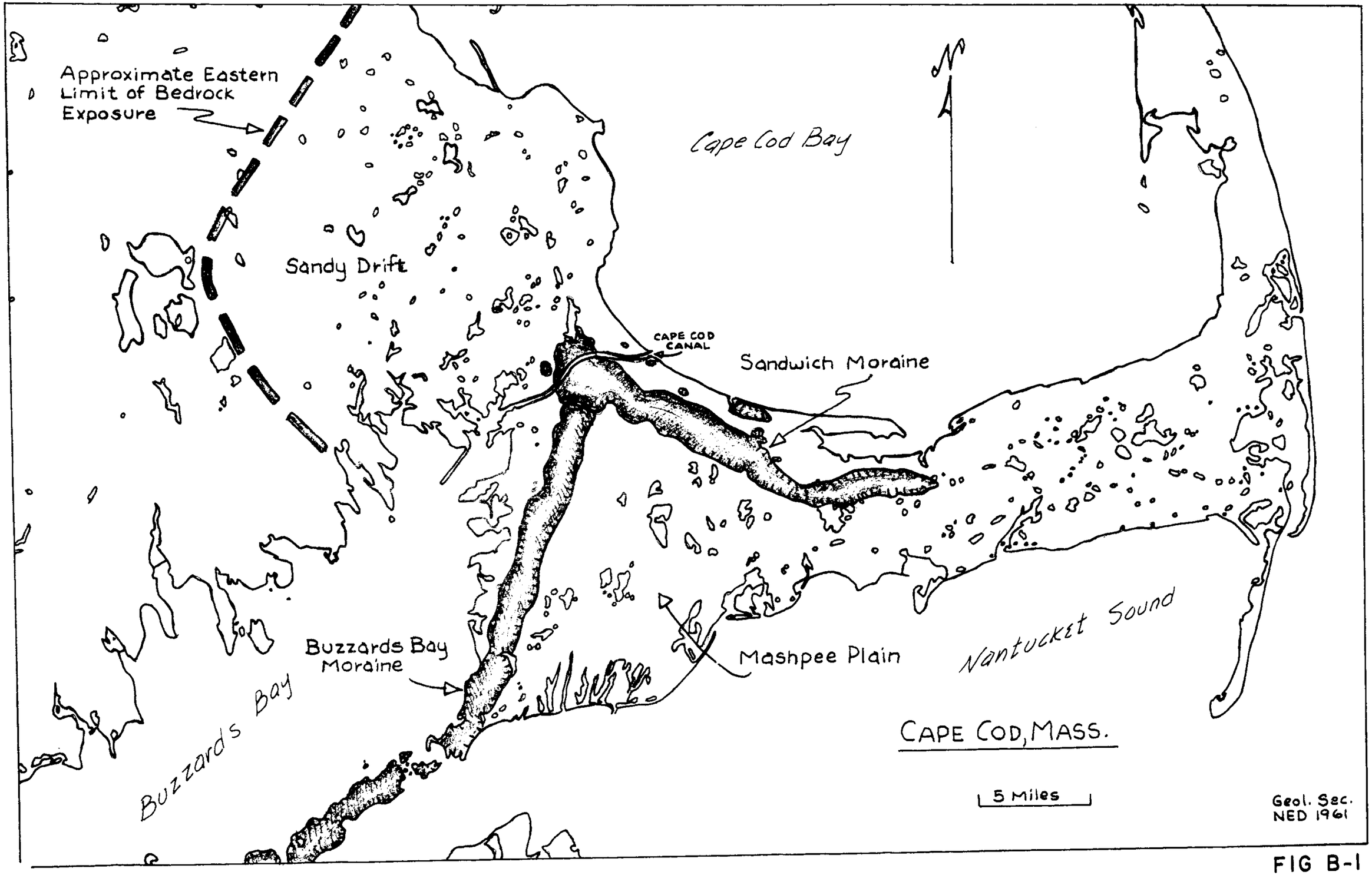

Approximate Eastern Limit of Bedrock Exposure
Cape Cod Bay
Sandy Drift
CAPE COD CANAL
Sandwich Moraine
Buzzards Bay Moraine
Mashpee Plain
Nantucket Sound
Buzzards Bay
CAPE COD, MASS.
5 Miles
Geol. Sec. NED 1961

FIG B-1

APPENDIX C

SAMPLES OF BEACH AND NEARSHORE MATERIAL

Samples of surface beach and nearshore materials were obtained along Profiles 1, 3, 6, 12, 18, 21 and 24. Locations of the profiles are shown on Plates 2, 3 and 4. Samples were obtained from the beaches at the berm and high and low water levels and offshore from the 6, 12, 18, 24 and 30 foot depths. A mechanical analysis was run of each sample and the results are included in Tables C-1, C-2, C-3 and C-4. Table C-1 contains information on the location of the samples, range of grain sizes, median diameters and character of material in per cent. Tables C-2, C-3 and C-4 contain cumulative weight percentages retained on various sieves for individual samples and for the average of all samples on each profile.

TABLE C-1. CHARACTERISTICS OF SAMPLES

Profile Number	Location on Profile	Grain Size (M M)		Character of Material, %					Remarks
		Range	Median Diameter	Gravel	Coarse Sand	Med. Sand	Fine Sand	Silt or Clay	
1	Berm	0.21-2.00	0.55		2.5	91.4	6.1		
	High Water	0.42-19.10	4.4	46.8	32.8	20.2	0.2		
	Low Water	0.21-50.8	30.5	65.1	2.2	31.0	1.7		
	6 ft.	0.15-19.10	0.76	17.5	11.4	65.1	6.0		
	12 ft.	0.074-25.4	1.1	17.3	9.9	61.1	9.6	2.1	
	18 ft.	0.074-12.70	0.63	4.8	3.2	76.9	11.9	3.2	
	24 ft.	0.074-4.76	0.41		0.5	48.3	48.0	3.2	
	30 ft.	0.15-19.10	0.60	11.2	11.8	47.9	29.1		
	AVERAGE		4.87						
3	1.5 ft.	0.59-19.10	3.2	36.9	29.2	33.9			Toe Revetment
	6 ft.	0.15-25.4	0.72	16.3	9.1	62.1	12.5		
	18 ft.	0.074-4.76	0.44		0.4	68.8	29.8	1.3	
	24 ft.	0.08-3.50	0.45		3.0	58.0	29.0		
	30 ft.	0.074-6.35	0.50	2.9	6.8	55.7	34.2	0.4	
	AVERAGE		1.06						
6	Low Water	0.21-19.10	1.1	5.9	2.0	91.1	1.0		Toe Revetment
	6 ft.	0.074-38.1	9.0	57.9	4.7	29.8	7.2	0.4	
	12 ft.	0.15-25.4	1.0	24.3	9.2	52.8	13.7		
	18 ft.	0.210-38.1	3.3	48.3	6.2	39.9	5.6		
	24 ft.	0.30-4.76	0.55		1.8	73.0	25.2		
	30 ft.	0.30-12.70	1.0	3.5	18.2	74.5	3.8		
	AVERAGE		2.66						

TABLE C-1. CHARACTERISTICS OF SAMPLES (Contd)

Profile Number	Location on Profile	Grain Size (M.M)		Character of Material, %					Remarks
		Range	Median Diameter	Gravel	Coarse Sand	Med. Sand	Fine Sand	Silt or Clay	
12	Berm	0.074-2.00	0.42			49.7	49.8	0.5	At Wall
	High Water	0.21-2.00	0.51			95.5	4.5		
	Low Water	0.21-19.10	0.60	6.2	7.5	75.7	10.6		
	6 ft.	0.074-4.76	0.27		0.8	13.5	84.9	0.8	
	12 ft.	0.074-25.4	5.6	55.0	10.1	20.8	11.5	2.6	
	18 ft.	0.074-19.10	0.43	5.7	8.1	39.8	35.6	10.8	
	24 ft.	0.074-19.10	0.45	11.3	8.6	35.9	41.1	3.1	
	30 ft.	0.074-25.4	0.75	23.2	11.7	29.8	31.2	4.1	
	AVERAGE		1.13						
18	Berm	0.074-2.00	0.52			75.5	24.5		
	High Water	0.15-19.10	1.0	24.0	15.1	29.3	31.6		
	Low Water	0.21-12.70	1.1	3.6	22.0	70.2	4.2		
	6 ft.	0.074-38.1	4.76	50.3	15.3	21.8	11.4	1.2	
	12 ft.	0.15-38.1	1.2	37.4	5.2	34.5	22.9		
	18 ft.	0.15-25.1	0.81	17.7	7.2	56.3	18.8		
	24 ft.	0.074-9.52	0.42	3.8	7.6	39.5	37.4	11.7	
	30 ft.	0.074-25.4	0.51	14.2	21.9	17.4	37.2	9.3	
	AVERAGE		1.29						

TABLE C-1. CHARACTERISTICS OF SAMPLES (Contd)

Profile Number	Location	Grain Size (M.M.)		Character of Material, %					Remarks
		Range	Median Diameter	Gravel	Coarse Sand	Med. Sand	Fine Sand	Silt or Clay	
21	Berm	0.15-38.1	2.6	41.7	12.9	32.0	13.4		
	High Water	0.21-19.10	4.5	48.9	10.1	19.1	21.9		
	Low Water	0.15-25.4	3.8	42.9	23.9	22.2	11.0		
	6 ft.	0.074-38.1	22.0	73.4	5.4	10.9	9.7	0.6	
	12 ft.	0.21-19.10	0.52	9.2	2.6	56.8	31.4		
	18 ft.	0.15-19.10	0.65	10.7	7.0	46.8	35.5		
	24 ft.	0.074-50.8	31.5	66.4	8.1	10.4	11.1	4.0	
	30 ft.	0.074-4.76	0.34		12.7	25.4	46.2	15.7	
	AVERAGE		8.24						
24	Berm	0.074-38.1	0.98	34.7	7.1	23.8	14.8	19.6	Toe Revetment
	High Water	0.42-38.1	2.00	37.4	10.3	52.3			
	Low Water	0.15-63.5	15.00	53.5	6.4	37.7	2.4		
	6 ft.	0.15-4.76	0.43		0.4	53.1	46.5		
	12 ft.	0.074-4.76	0.28		0.8	34.2	63.8	1.2	
	18 ft.	Weeds							
	24 ft.	1 Stone 1½ in.Ø							
	30 ft.	Shells + Organic Matter							
	AVERAGE		3.74						

TABLE C-2. SIEVE ANALYSIS

U.S. STANDARD SIEVE NO. DIAMETER IN MM	1½" 38.1	1" 25.4	3/4" 19.10	1/2" 12.70	3/8" 9.52	4 4.76	10 2.00	20 0.84	30 0.59	40 0.42	50 0.297	70 0.210	80 0.177	100 0.149	200 0.074	PAN
LOCATION	CUMULATIVE WEIGHT PERCENTAGE RETAINED															
							Profile No. 1									
Berm								6.5	6.5	93.9	98.1	99.5	99.5	100.0	100.0	100.0
High Water				2.5	11.3	46.8	79.6	91.2	98.0	99.8	100.0	100.0	100.0	100.0	100.0	100.0
Low Water	37.0	58.0	58.0	62.0	63.1	65.1	67.3	80.4	91.7	98.3	99.4	99.8	99.8	100.0	100.0	100.0
6 Ft.				4.6	7.9	17.5	28.9	41.6	69.9	94.0	95.9	98.4	98.4	99.7	100.0	100.0
12 Ft.			1.8	3.5	8.3	17.3	27.2	62.3	77.0	88.3	89.7	90.7	90.7	92.8	97.9	100.0
18 Ft.					0.6	4.8	8.0	33.1	59.5	84.9	90.4	90.4	92.3	92.9	96.8	100.0
24 Ft.							0.5	11.4	25.4	48.8	63.3	72.8	72.8	78.2	96.8	100.0
30 Ft.				0.9	3.0	11.2	23.0	40.5	51.0	70.9	87.5	96.8	96.8	98.4	100.0	100.0
TOTALS	37.0	58.0	59.8	73.5	94.2	162.8	234.5	367.0	479.0	678.9	724.3	748.4	750.3	762.0	791.5	800.0
AVERAGE CUM.	4.6	7.3	7.5	9.2	11.8	20.4	29.3	45.9	59.9	84.9	90.5	93.6	93.8	95.3	98.9	100.0

TABLE C-2. SIEVE ANALYSIS (Contd)

U.S. STANDARD SIEVE NO. DIAMETER IN MM	1½" 38.1	1" 25.4	3/4" 19.10	1/2" 12.70	3/8" 9.52	4 4.76	10 2.00	20 0.84	30 0.59	40 0.42	50 0.297	70 0.210	80 0.177	100 0.149	200 0.074	PAN
LOCATION	CUMULATIVE WEIGHT PERCENTAGE RETAINED															
							Profile No. 3									
1.5 Ft.*				6.9	12.9	36.9	66.1	93.7	99.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0
6 Ft.			2.5	9.0	10.5	16.3	25.4	43.3	64.5	87.5	93.0	97.4	97.4	98.9	100.0	100.0
18 Ft.							0.4	3.5	20.3	69.2	85.1	90.8	90.8	93.0	98.7	100.0
24 Ft.							3.0	21.2	34.6	61.0	83.1	94.8	94.8	97.0	100.0	100.0
30 Ft.						2.9	9.7	29.5	43.4	65.4	82.7	96.2	96.2	98.3	99.6	100.0
TOTALS			2.5	15.9	23.4	56.1	104.6	191.2	262.5	383.1	443.9	479.2	479.2	487.2	498.3	500.0
AVERAGE CUM.			0.5	3.2	4.7	11.2	20.9	38.2	52.5	76.6	88.8	95.8	95.8	97.4	99.7	100.0

*Toe Stone Revetment

TABLE C-2. SIEVE ANALYSIS (Contd)

U.S. STANDARD SIEVE NO. DIAMETER IN MM	1½" 38.1	1" 25.4	3/4" 19.10	1/2" 12.70	3/8" 9.52	4 4.76	10 2.00	20 0.84	30 0.59	40 0.42	50 0.297	70 0.210	80 0.177	100 0.149	200 0.074	PAN
LOCATION	CUMULATIVE WEIGHT PERCENTAGE RETAINED															
							Profile No. 6									
Low Water*				4.3	5.1	5.9	7.9	73.2	91.4	99.0	99.0	99.0	99.0	100.0	100.0	100.0
6 FT.		19.7	32.6	45.8	50.5	57.9	62.6	71.2	80.6	92.4	96.0	98.2	98.2	98.9	99.6	100.0
12 Ft.			2.5	8.4	14.2	24.3	33.5	56.7	69.8	86.3	94.3	98.8	98.8	99.4	100.0	100.0
18 Ft.		15.7	22.6	38.3	44.9	48.3	54.5	69.5	80.3	94.4	98.7	99.7	100.0	100.0	100.0	100.0
24 Ft.							1.8	7.6	26.2	74.8	98.3	100.0	100.0	100.0	100.0	100.0
30 Ft.					0.5	3.5	21.7	64.0	82.9	96.2	98.6	100.0	100.0	100.0	100.0	100.0
TOTALS		35.4	57.7	96.8	115.2	139.9	182.0	342.2	421.2	543.1	584.9	595.7	596.0	598.3	599.6	600.0
AVERAGE CUM.		5.9	9.6	16.1	19.2	23.3	30.3	57.0	70.2	90.5	97.5	99.3	99.3	99.7	99.9	100.0

*Toe Stone Revetment

TABLE C-3. SIEVE ANALYSIS

U.S. STANDARD SIEVE NO. DIAMETER IN MM	1½" 38.1	1" 25.4	3/4" 19.10	1/2" 12.70	3/8" 9.52	4 4.76	10 2.00	20 0.84	30 0.59	40 0.42	50 0.297	70 0.210	80 0.177	100 0.149	200 0.074	PAN
LOCATION	CUMULATIVE WEIGHT PERCENTAGE RETAINED															
							Profile No. 12									
Berm at Wall								0.5	0.5	49.7	82.4	98.5	99.0	99.0	99.5	100.0
High Water								14.7	14.7	95.5	98.0	99.0	100.0	100.0	100.0	100.0
Low Water				0.8	2.2	6.2	13.7	30.9	55.1	89.4	95.1	98.2	98.2	100.0	100.0	100.0
6 Ft.							0.8	3.2	5.6	14.3	37.9	86.2	86.2	94.1	99.2	100.0
12 Ft.			10.5	27.5	36.7	55.0	65.1	73.4	78.6	85.9	90.1	93.4	93.4	94.8	97.4	100.0
18 Ft.				0.5	1.5	5.7	13.8	28.1	37.2	53.6	68.3	76.7	76.7	79.8	89.2	100.0
24 Ft.				1.4	3.6	11.3	19.9	31.2	39.8	55.8	74.6	86.7	86.7	90.6	96.9	100.0
30 Ft.			8.9	11.9	15.1	23.2	34.9	47.6	54.1	64.7	74.7	83.1	83.1	86.9	95.9	100.0
TOTALS			19.4	42.1	59.1	101.4	148.2	229.6	285.6	508.9	621.1	721.8	723.3	745.2	778.1	800.0
AVERAGE CUM.			2.4	5.3	7.4	12.7	18.5	28.7	35.7	63.6	77.6	90.2	90.4	93.2	97.3	100.0

TABLE C-3. SIEVE ANALYSIS (Contd)

U.S. STANDARD SIEVE NO. DIAMETER IN MM	1½" 38.1	1" 25.4	3/4" 19.10	1/2" 12.70	3/8" 9.52	4 4.76	10 2.00	20 0.84	30 0.59	40 0.42	50 0.297	70 0.210	80 0.177	100 0.149	200 0.074	PAN
LOCATION	CUMMULATIVE WEIGHT PERCENTAGE RETAINED															
							Profile No. 18									
Berm								14.5	14.5	75.5	90.0	98.0	99.0	99.0	99.0	100.0
High Water				4.1	9.1	24.0	39.1	53.3	62.1	68.4	79.1	97.8	97.8	99.7	100.0	100.0
Low Water					0.6	3.6	25.6	82.1	90.8	95.8	97.2	98.6	98.6	100.0	100.0	100.0
6 Ft.		13.7	16.3	36.3	41.6	50.3	65.6	78.6	83.1	87.4	89.8	93.7	93.7	96.6	98.8	100.0
12 Ft.		6.8	12.3	20.7	28.1	37.4	42.6	54.6	62.5	77.1	89.5	97.4	97.4	98.9	100.0	100.0
18 Ft.			3.2	6.0	9.7	17.7	24.9	49.2	62.0	81.2	93.1	99.2	99.2	99.6	100.0	100.0
24 Ft.						3.8	11.4	24.8	34.5	50.9	64.3	76.1	76.1	78.6	88.3	100.0
30 Ft.			1.3	1.6	2.8	14.2	36.1	44.2	47.7	53.5	59.9	69.2	69.2	74.0	90.7	100.0
TOTALS		20.5	33.1	68.7	91.9	151.0	245.3	401.3	457.2	589.8	662.9	730.0	731.0	746.4	776.8	800.0
AVERAGE CUM.		2.6	4.2	8.6	11.5	18.9	30.7	50.2	58.2	73.7	82.9	91.3	91.4	93.3	97.1	100.0

TABLE C-4. SIEVE ANALYSIS

U.S. STANDARD SIEVE NO. DIAMETER IN MM	2" 50.8	1½" 38.1	1" 25.4	3/4" 19.10	½" 12.70	3/8" 9.52	4 4.76	10 2.00	20 0.84	30 0.59	40 0.42	50 0.297	70 0.210	80 0.177	100 0.149	200 0.074	PAN
LOCATION	CUMULATIVE WEIGHT PERCENTAGE																
							Profile No. 21										
Berm			5.7	16.3	27.5	33.5	41.7	54.6	67.2	74.0	86.6	95.1	99.3	99.3	99.8	100.0	100.0
High Water					15.3	26.6	48.9	59.0	65.6	69.9	78.1	90.2	98.4	100.0	100.0	100.0	100.0
Low Water				7.5	16.6	27.7	42.9	66.8	77.2	81.9	89.0	94.8	98.9	98.9	99.7	100.0	100.0
6 Ft.			38.2	55.8	62.4	66.8	73.4	78.8	82.9	85.4	89.7	92.9	96.1	96.1	97.5	99.4	100.0
12 Ft.					1.7	4.5	9.2	11.8	30.3	45.4	68.6	86.7	97.0	97.0	100.0	100.0	100.0
18 Ft.					1.0	3.7	10.7	17.7	35.1	45.8	64.5	83.2	96.7	96.7	98.8	100.0	100.0
24 Ft.		42.5	56.4	56.4	58.6	60.4	66.4	74.5	80.3	82.2	84.9	87.0	89.1	89.1	90.3	96.0	100.0
30 Ft.								12.7	27.4	31.5	38.1	44.7	56.9	56.9	64.0	84.3	100.0
TOTALS		42.5	100.3	136.0	183.1	223.2	293.2	375.9	466.0	516.1	599.5	674.6	732.4	734.0	750.1	779.7	800.0
AVERAGE CUM.		5.3	12.5	17.0	22.9	27.9	36.7	47.0	58.3	64.5	74.9	84.3	91.6	91.8	93.8	97.5	100.0

TABLE C-4. SIEVE ANALYSIS

U.S. STANDARD SIEVE NO. DIAMETER IN MM	2" 50.8	1½" 38.1	1" 25.4	3/4" 19.10	½" 12.70	3/8" 9.52	4 4.76	10 2.00	20 0.84	30 0.59	40 0.42	50 0.297	70 0.210	80 0.177	100 0.149	200 0.074	PAN
LOCATION	CUMULATIVE WEIGHT PERCENTAGE																
							Profile No. 24										
Berm*			6.0	19.6	21.5	24.7	34.7	41.8	53.0	58.4	65.6	70.5	75.0	75.0	76.8	80.4	100.0
High Water			35.6	35.6	35.6	35.9	37.4	47.7	91.9	98.4	99.7	100.0	100.0	100.0	100.0	100.0	100.0
Low Water	39.1	39.1	46.5	49.6	50.2	51.0	53.5	59.9	86.7	94.6	97.6	98.2	99.1	99.1	99.4	100.0	100.0
6 Ft.								0.4	7.0	16.6	53.5	77.2	94.3	94.3	98.7	100.0	100.0
12 Ft.								0.8	7.1	17.1	35.0	45.8	82.5	82.5	92.1	98.8	100.0
18 Ft.	WEEDS																
24 Ft.	ONE STONE - 1½" Ø																
30 Ft.	SHELLS + ORGANIC MATTER																
TOTALS	39.1	39.1	88.1	104.8	107.3	111.8	125.6	150.6	245.7	285.1	351.4	391.7	450.9	450.9	467.0	479.2	500.0
AVERAGE CUM.	7.8	7.8	17.6	21.0	21.5	22.4	25.1	30.1	49.1	57.0	70.3	78.3	90.2	90.2	93.4	95.8	100.0

*Toe stone revetment.

APPENDIX D

PREVAILING WINDS AND STORMS

1. Prevailing Winds. - United States Weather Bureau wind records at Nantucket, Massachusetts, located about 30 miles offshore, southeast of the study area, show that the prevailing wind direction is west southwest and that winds blow from westerly directions about two-thirds of the time. Hourly observations of wind speeds and directions for a duration of seven years including the periods August 1952 to July 1957 and August 1958 to July 1960 were used. A wind rose based on these observations is shown on Plate 1 and a tabulation showing wind duration by direction and speeds is included in Table D-1, below. Onshore winds from the southwest quadrant have a slightly longer duration than the offshore winds from the northwest quadrant and they have about double the duration of onshore winds from the southeast quadrant. Winds 32 miles per hour and greater, however, have the longest duration from the north northeast, west and west northwest in that order.

TABLE D-1

WIND SPEEDS AND DIRECTIONS NANTUCKET, MASSACHUSETTS

AUGUST 1952 - JULY 1957 AND AUGUST 1958 - JULY 1960, INCLUSIVE

Wind Speed M. P. H.	DURATION IN HOURS 0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	>47	Total Duration Hrs.	% Total Duration	Ave. Speed MPH	Wind Movement Miles	% Total Movement	% Duration Per Degree
DIRECTION															
N	64	449	1,145	1,179	502	164	30	6	3	3,542	5.8	13.8	49,040	6.0	0.27
NNE	59	281	760	1,053	566	253	65	16	1	3,054	5.0	15.8	48,366	5.9	0.26
NE	91	452	926	805	359	135	14			2,782	4.5	12.7	35,452	4.3	0.19
ENE	57	352	808	742	394	124	34	6		2,517	4.1	14.0	35,238	4.3	0.19
E	66	314	640	640	299	92	17	8	1	2,077	3.4	13.6	28,276	3.4	0.15
ESE	59	287	797	709	348	148	34	5	2	2,389	3.9	13.9	33,203	4.0	0.18
SE	56	284	776	593	198	48	16	4	1	1,976	3.2	12.6	24,879	3.0	0.13
SSE	48	376	1,416	1,093	275	68	17	1	3	3,297	5.4	12.6	41,443	5.0	0.22
S	73	478	1,448	1,168	380	82	17	2	2	3,650	5.9	12.6	46,009	5.6	0.25
SSW	47	384	1,593	1,681	555	104	16	3	1	4,384	7.1	13.6	59,782	7.3	0.32
SW	76	450	2,411	2,468	505	99	14	4		6,027	9.8	13.1	78,737	9.5	0.42
WSW	53	549	2,291	2,591	739	160	40	1		6,424	10.5	13.6	87,490	10.6	0.47
W	67	513	1,419	1,345	462	149	54	4		4,013	6.5	13.6	54,410	6.6	0.29
WNW	87	731	2,116	1,960	787	277	44	6		6,008	9.8	13.7	82,015	10.0	0.44
NW	96	722	1,425	1,442	511	165	18	2	1	4,382	7.1	12.8	55,964	6.8	0.30
NNW	51	456	1,412	1,750	671	158	21	1		4,520	7.4	14.0	63,480	7.7	0.34
CALMS										346	0.6				
TOTALS	1,050	7,078	21,383	21,219	7,551	2,226	451	69	15	61,388	100.0	13.4	823,784	100.0	

2. Storm Winds. - A summary of winds, each with a continuous duration of at least four hours and wind speeds of 30 miles per hour or higher was prepared based on United States Weather Bureau hourly observations at Nantucket, Massachusetts. The summary covers a duration of nine years including three separate periods from January 1945 to June 1960 and it is included in Table D-2, below.

TABLE D-2

* NINE-YEAR SUMMARY OF WINDS 30 MILES PER HOUR OR HIGHER

AT NANTUCKET, MASSACHUSETTS

Direction	No. of Occurrences	Total Duration Hours	Total Duration Percent	Average Duration Hours	Average Speed M.P.H.	Total Movement Miles
N	9	100	8.8	11	35	3499
NNE	13	179	15.7	14	35	6275
NE	9	126	11.1	14	37	4681
ENE	9	111	9.8	12	38	4251
E	5	60	5.3	12	36	2182
ESE	9	62	5.5	7	34	2134
SE	6	34	3.0	6	33	1121
SSE	1	4	0.4	4	30	120
S	4	22	1.9	6	33	717
SSW	4	18	1.6	5	32	578
SW	4	45	4.0	11	34	1531
WSW	11	103	9.1	9	33	3405
W	8	99	8.7	12	34	3330
WNW	10	73	6.4	7	33	2400
NW	12	88	7.8	7	34	3002
NNW	2	10	0.9	5	33	334

* Includes Jan 1945-Dec 1950; July 1956-June 1957 and July 1958-June 1960 inclusive.

The tabulation shows that north northeast winds occur most frequently and have the longest duration and that east northeast and northeast winds have the highest average speeds. Approximately 44 percent of the duration of all winds occurs from the northeast quadrant, almost double the next longest duration (24 percent) which occurs from the northwest quadrant. Of the onshore winds, approximately 20 percent of the duration is from the southwest quadrant and 12 percent from the southeast quadrant.

APPENDIX E

TIDES

1. General. - Tides in the study area are semi-diurnal. Mean ranges are 1.5 feet at Nobska Point, 1.3 feet at Falmouth Heights, Falmouth Inner Harbor and Woods Hole (Little Harbor) and 1.1 feet in Waquoit Bay. Spring ranges are 1.9 feet at Nobska Point and 1.6 feet at Falmouth Heights and Woods Hole (Little Harbor).

2. Tidal Observations. - The higher tides observed by the United States Coast and Geodetic Survey for the short periods listed below were compared with tides observed at reference stations at Newport, Rhode Island or Boston, Massachusetts to determine if variations above the mean range were comparable.

Location	Period
Woods Hole (Little Harbor)	May 23 - Aug. 31, 1938
Falmouth Heights	May 20 - Oct. 3, 1942
Falmouth Inner Harbor	Sept. 8 - Nov. 30, 1934
Waquoit Bay	Sept. 11 - 27, 1939

Variations above the mean range of five tides at Waquoit Bay were from 0.6 of a foot below to 0.8 of a foot above those at Newport. Similar variations of 10 tides at Falmouth Inner Harbor ranged from 0.0 to 0.8 of a foot above those at Newport. At Woods Hole (Little Harbor) 21 tides ranged from 0.0 to 0.6 of a foot below Newport and 10 tides ranged from 0.6 to 0.9 of a foot below Boston. At Falmouth Heights, of 34 tides compared with Newport, variations above the mean range of 18 were up to 1.2 feet higher, of 15 were up to 0.8 of a foot lower and 1 was the same, while 10 tides compared with Boston were all 0.8 to 1.5 feet lower. The above comparison indicates that individual higher tides which occur at Falmouth vary considerably from those at Newport or Boston and that they are generally lower than at Boston.

3. Frequency of Higher Tides. - The frequency of occurrence of tides which exceeded the mean range by 2.0 feet or more, based on 30-1/3 years of observations at Boston, Massachusetts and 10 years of observations at Newport, Rhode Island are shown in the following tabulation.

Feet Above Mean High Water	Average Annual Number of Occurrences		
	Boston, Mass.	Newport, R.I.	Falmouth (Est.)
4.3	0.03	0.0	0.02
4.2	0.06	0.0	0.03
4.1	0.06	0.0	0.03
4.0	0.06	0.0	0.03
3.9	0.06	0.0	0.03
3.8	0.06	0.1	0.08
3.7	0.1	0.1	0.1
3.6	0.1	0.1	0.1
3.5	0.2	0.1	0.1
3.4	0.2	0.1	0.2
3.3	0.5	0.2	0.3
3.2	0.7	0.2	0.5
3.1	1.1	0.3	0.7
3.0	1.5	0.6	1.0
2.9	2.2	0.6	1.4
2.8	2.7	0.9	1.8
2.7	3.6	1.1	2.4
2.6	4.8	1.2	3.0
2.5	6.8	1.4	4.1
2.4	9.1	2.0	5.5
2.3	11.8	2.7	7.3
2.2	15.3	4.5	9.9
2.1	18.5	6.5	12.5
2.0	24.5	9.4	17.0

It is evident from the tabulation that higher tides occur with greater frequency at Boston than at Newport. It appears from available observations that the frequency of occurrence of the higher tides at Falmouth is smaller than at Boston and it may be greater or smaller than at Newport. Higher tidal heights above mean high water which occur once a year, average between 2.7 and 2.8 feet at Newport and between 3.1 and 3.2 feet at Boston. The higher tidal heights which occur at Falmouth may be between those at Newport and Boston, in which case a tide 3.0 feet above mean high water may occur about once a year. The estimated frequency of occurrence of the higher tides at Falmouth based on the assumption that they are about midway between Newport and Boston are shown in the above tabulations.

4. Extreme High Tides. - The heights above mean low water of the highest tides of record which occurred during recent hurricanes are tabulated below:

Location	Sept. 21, 1938	Sept. 14-15, 1944	Aug. 31, 1954
Little Hbr. and Nobska Point	10.0	—	—
Falmouth Inner Hbr.	——	9.2	9.5
Falmouth Heights	8.6	12.7	—
Waquoit Bay	—	11.6	—

APPENDIX F

SHORELINE AND OFFSHORE DEPTH CHANGES

1. General. - Shoreline changes were determined from comparative positions of the high water shoreline located by the United States Coast and Geodetic Survey in 1845-46, 1888-91, 1938-41 and 1948, by the Corps of Engineers, United States Army in 1961 and from surveys by the Town of Falmouth, the latter covering only the Falmouth Heights section, during October 1947, June and December 1957 and November 1958. Offshore depth changes were determined from the depth contours out to 30 feet located by the United States Coast and Geodetic Survey in 1845, 1854, 1887, 1938 and 1954 and from beach profiles by the Corps of Engineers, United States Army in 1961. Amounts of change were scaled from available maps. Due to the scales of the maps, amounts of changes determined were approximate. The indicated movements of the 6 and 12-foot contours from 1845 to 1854 and then to 1887 appear anomalous in that they show a seaward movement of up to 800 feet between 1845 and 1854 and a landward movement of the same magnitude between 1854 and 1887 returning the contours to their 1845 positions. The shoreline and offshore depth changes are shown on Plates 5 to 10 inclusive. In the following descriptions, locations of shoreline changes are designated by a shoreline station numbering system shown on Plates 9 and 10.

2. Shoreline Changes. - a. Nobska Point. The shoreline of the outer tip of Nobska Point, the westerly 600 feet of this section, moved up to 50 feet seaward between 1845-46 and 1888-91 with little change from 1891 to 1948, the last survey of record. The rest of this area, from Station 6 to 18 generally receded between 1845 and 1961 for varying distances up to 75 feet.

b. Between Nobska Point and Falmouth Beach. The shoreline generally receded along the westerly third of the area between 1845 and 1941 for distances varying irregularly from about 90 feet at Station 18 to 40 feet at Station 38 and it moved seaward a similar amount to about its 1845 position from 1941 to 1961. There was a recession of 100 to 25 feet generally decreasing eastward from Station 38 to 56 between 1845 and 1941 and accretion from 1941 to 1961 of 75 to 100 feet, the latter in the form of fillets at the west sides of groins. Along the easterly portion of the area from Stations 56 to 76, there was a recession between 1845 and 1961 increasing eastward from about 25 to 75 feet and little or no change from 1941 to 1961.

c. Falmouth Beach. - There was accretion and a varying seaward shoreline movement, generally less than 50 feet, along the west half of Falmouth Beach (Station 76 to 108) between 1845 and 1891 with little or no change along the east half. From 1891 to 1941 the westerly part of the beach from Station 76 to 135 receded about 90 to 25 feet, respectively, while the only significant change east of this area was accretion of 25 and 50 feet just west of and within the breakwaters at the east end of the beach. There was little or no change from 1941 to 1961 except for additional accretion at the east end of the beach of 25 and 75 feet immediately west of and within the breakwaters.

d. Between Falmouth Beach and Falmouth Inner Harbor. - A recession of up to 50 feet occurred along the easterly half of this area between 1845 and 1891. From 1891 to 1941 all but the east end of the shoreline receded 25 to 50 feet. At the east end along 600 feet of shore west of a jetty built at the harbor entrance in 1909, accretion occurred in the form of a fillet with a greatest width at the jetty of 150 feet. From 1941 to 1961, the only significant change was additional accretion along 300 feet of the easterly end of the beach at the fillet west of the harbor jetty, which moved the shoreline up to 100 feet seaward.

e. Falmouth Heights. - Principal changes between 1845 and 1891 consisted of a 600-foot westward movement of the Falmouth Inner Harbor entrance and a 50 to 75-foot recession of the westerly 1500 feet of shore (Station 185 to 200). From 1891 to 1941 there was a general recession of 50 to 75 feet along the convex shore from the harbor entrance to the east end of the bluffs (Station 185 to 217), about 25 feet along the concave shore to the east (Station 217 to 235) and a larger recession increasing to about 80 feet at the east limit. There was a general accretion of the shore between 1941 and 1961 due to placement of about 120,000 cubic yards of fill in front of part of this area (Station 199 to 217, approximately) during 1957 from the Falmouth Inner Harbor dredging and subsequent drifting. Up to 1961, this fill moved the shore line along the westerly 1300 feet of shore (west of Station 199) 50 to 75 feet seaward of its 1941 position. Around the bluffs area (Station 199 to 217) where the fill was placed directly on the beach, the shore line was moved seaward 80 feet at the groin at the west end, increasing to 160 feet in the vicinity of Station 205 and thence decreasing gradually to no change at the groin at the east end as measured from Town of Falmouth surveys of October 1947 and June 1957. The fill was eroded rapidly from most of this area resulting in a recession of up to 65 feet from June 1957 to December 1957, up to 60 feet from December 1957 to November 1958 and up to 40 feet from November 1958 to July 1961. The groin at the east end, at Station 216+50, impounded some of the fill between June 1957 and July 1961 for about 180 feet on its west side with a maximum seaward short line movement of 45 feet at the groin. East of Station 216+50, the four shore pockets

formed by groins were filled in succession from west to east. The westerly pocket was filled in June 1957 and was still full in July 1961, the second was almost filled by November 1958 and was completely filled in July 1961, the third was about one-third filled in November 1958 and completely filled in July 1961 and the fourth pocket had a small amount of accretion by November 1958 and it received a large additional amount up to July 1961. Amounts of seaward shoreline movement from October 1947 to July 1961 in the pockets were as follows: first, 65 to 125 feet; second, 90 to 130 feet; third 55 to 90 feet; and fourth, 40 to 70 feet.

f. Mara Vista. - Changes between 1845 and 1891 consisted of a 250-foot westward movement of the Little Pond entrance to its approximate present position and a general shoreline recession of 50 to 75 feet. An additional recession occurred from 1891 to 1941 along the westerly portion of this area (Station 241 to 257) with a shoreline movement of 75 feet at the west limit decreasing eastward gradually to a point of no change. Shoreline changes between 1941 and 1961 were small consisting of slight accretion at the west end and recession at the east end with no change in the center of the area.

g. Acapesket. - This area has been subject to large changes. The Green Pond entrance moved about 1000 feet westward from 1845 to 1891 and thence about 300 feet eastward from 1891 to 1941 and another 100 feet eastward to 1961. The shoreline receded up to 100 feet between 1845 and 1891 and up to 200 feet more from 1891 to 1941 along the westerly half of the area (Station 266 to 284). Changes in this section from 1941 to 1961 were smaller, consisting principally of recession of about 200 feet immediately adjacent to the Great Pond east jetty and accretion of up to about 50 feet in the form of fillets at the west sides of groins. The easterly portion of the area (Station 284 to 295) receded about 400 feet from 1845 or 1891 to 1941 and up to about 200 feet more from 1941 to 1961.

h. Davisville. - The principal shoreline changes of record were the movements in the position of the Green Pond entrance described in the preceding paragraph and the recession of the shoreline. This shore recession between 1845 and 1941 amounted to about 300 feet at the ends and generally 100 to 150 feet along the rest of the area. From 1941 to 1961, shoreline movements consisted of recession, generally less than 25 feet along the west half and accretion of 25 to 50 feet along the east half of the area.

i. Menauhant. - The shoreline receded from 1845 to 1891 to 1942 for total distances varying from 100 feet at the west end to 300 feet in the center and 200 feet at the east end of the area. From 1942 to 1961, the shoreline moved seaward about 25 to 50 feet along most of the west half of the area (Station 332 to 346) and it receded a similar amount along the east end (Station 352 to 359). The shoreline from Menauhant

to Washburn Island was continuous during 1845 and 1891 with no opening into Eel Pond. The first opening into the pond is shown by the 1938-41 shoreline but during 1942 the shoreline was again continuous. During 1961, the opening again existed in a larger form about 250 feet east of its 1938-41 location.

j. Washburn Island. - The entire shore line receded generally about 100 feet from 1845 to 1891. From 1891 to 1942 there was additional recession along the westerly portion of the area with a shore movement of about 200 feet at the extreme west end at Station 360. This movement decreased eastward to no change from Station 380 to 395 and there was accretion along the shore east of Station 395, the amount of shore movement increasing eastward to about 300 feet at the Waquoit Bay entrance where a jetty built during 1937 impounded material. Changes from 1942 to 1961 consisted of a shore recession along the west half, the amount of movement gradually increasing westward from no change at Station 390 to about 500 feet at the Eel Pond entrance while accretion occurred east of this area with a seaward shore movement of up to, but generally less than, 100 feet.

3. Offshore Depth Changes. - The 1938 and 1954 depth contours and Profile 24 run during 1961 indicate that there were no large recent depth changes off Nobska Point. Between Nobska Point and Falmouth Beach, from 1887 to 1938, the 6-foot depth contour moved seaward throughout, the 12-foot contour moved seaward opposite the west end of the area and landward opposite the east end, and the 18 and 30-foot contours generally moved landward. From 1938 to 1954, where the 1954 contours are available only along part of the shore, there was no depth change. From 1954 to 1961, the only significant changes were accretion at the 30 foot depth at Profile 23 and also at the 6, 12, 18 and 30-foot depths at Profile 22. Changes opposite Falmouth Beach between 1887 and 1938 consisted of deepening in the vicinity of the 6 and 12-foot depths, irregular changes, alternately deepening and shoaling in the vicinity of the 18-foot depth and shoaling along the 30-foot depth. From 1938 to 1961, there was little or no depth change out to the 30-foot contour at Profiles 18 through 21 inclusive.

Between Falmouth Beach and Falmouth Inner Harbor, the 6, 12, 18 and 30-foot contours generally moved landward from 1887 to 1938 indicating deepening. This offshore deepening continued from 1938 to 1961 at the 6, 12, 18 and 30-foot depths at Profile 17.

Changes opposite Falmouth Heights from 1845 to 1938 consisted principally of deepening in the vicinity of the 6 and 12-foot depths and irregular changes in the vicinity of the 18 and 30 foot depths, principally deepening and shoreward movement of contours along the westerly end of the area and shoaling accompanied by seaward contour movements along the greater part of the area located to the east. From 1938 to 1961 a small amount of deepening occurred generally out to the 30-foot depth at Profiles 12 and 16.

Offshore depth changes opposite the Mara Vista shore from 1845 to 1938 consisted of deepening in the vicinity of the 6 and 12-foot depths and shoaling at the 18 and 30-foot depths. From 1938 to 1961 at Profiles 7 and 8 deepening occurred at the 6, 12 and 18-foot depths and little or no change at the 30-foot depth.

At Acapesket, from 1845 to 1938, offshore deepening occurred at the 6, 12 and 18-foot depths and irregular changes, principally shoaling in the vicinity of the 30-foot depth. From 1938 to 1961 there was shoaling at the 18 and 30-foot depths and deepening at the 6-foot depth on Profile 6.

Along the Davisville and the westerly third of the Menauhant shore there was deepening in the vicinity of the 6-foot depth from 1845 to 1938 while shoaling occurred at the 6-foot depth along the easterly two-thirds of the Menauhant shore, and in the vicinity of the 12, 18 and 30-foot depths opposite all of the Davisville and Menauhant shores. From 1938 to 1961 there was shoaling at the 12 and 18-foot depths and deepening at the 6-foot depth on Profiles 4 and 5 and deepening at the 6 and 18-foot depths at Profile 3 opposite Washburn Island; from 1845 to 1938, irregular changes mostly shoaling, occurred in the vicinity of the 30-foot depth. Lack of comparative contours does not permit determination of depth changes for this period inshore of the 30-foot depth. From 1845 to 1961, the principal changes were deepening at the 12 and 18-foot depths at Profile 2 while at Profile 1 there was deepening at the 12-foot depth and shoaling at the 18 and 30-foot depths.

APPENDIX G

PRIOR AND EXISTING PROTECTIVE STRUCTURES

Available information concerning prior and existing protective structures is listed below. Information is listed to correspond with the identifying numbers used on Plates 2, 3 and 4.

1. Stone mound and riprap revetment at Nobska Point. Constructed by the Massachusetts Department of Public Works during 1959 to stop the serious erosion of the bluff and to protect the shore road. The protection included 1,100 feet of the point. The stone mound at the toe of the bluff has a top elevation of 12.0 feet above mean low water, a top width of 5 feet, a seaward slope of 1 on 2, a landward slope of 1 on 1, a minimum height at its center line of 4 feet and a minimum toe thickness of 3 feet. Slope revetment above the mound was placed up to elevation 20.0 feet at a slope of 1 on 2 with a minimum thickness of 4 feet. Stone chips were used to chink the heavier armor stone and a 12-inch layer of crushed stone was placed on the landward slope of the mound between the ordinary borrow backfill and the bottom half of the riprap revetment. The backfilled slope above the structure was covered with 6 inches of loam and seeded. The structure is generally in good condition. There are voids in a few small areas where stones have been displaced.

2. A pile of stones, the probable remains of a stone groin.

3. Dumped riprap revetment along the edge of the road.

4. Three deteriorated stone groins.

5. Stone wall fronted with mortared sloping stone revetment. Good condition.

6. Three timber open pile piers.

7. Timber bulkhead at toe of bluff fronted by riprap revetment.

8. Five stone groins, fair to good condition.

9. Stone revetment at toe of bluffs in good condition.

10. Low rubble masonry wall in good condition.

11. Stone groin in good condition.

12. Stone groin bound with Portland Cement mortar. Good condition.

13. Stone groin.

14. Open timber pile pier.

15. Dumped riprap along edge of the railroad.

16. Dumped riprap along edge of road.

17. Stone groins, the westerly one in need of repairs, the other in good condition.

18.) Four stone groins (18) and two stone jetties (19) constructed 19.)
by the Massachusetts Department of Public Works in 1948 to prevent erosion of the beach and silting of the Salt Pond inlet. From west to east, groin lengths were 135, 135, 125 and 125 feet and jetties were 125 and 75 feet. All structures were built to a top width of 5 feet, a top elevation of 7.0 feet above mean low water for the inner 75 feet sloping down to elevation 2.5 feet at their outer ends and side slopes of 1 on 1.5. Jetties were 29 feet between their center lines. Structures included cores of smaller stones. They were all rebuilt in 1955 to their original dimensions. They are generally in good condition.

20. Stone groin and two open timber pile piers, all in good condition.

21. Two stone jetties flanking the Siders Pond drainage culvert. Structures in good condition. During inspection in November 1961, a sand bar had formed across the inlet stopping the drainage.

22. Two curved and converging stone breakwaters fronting the town-owned beach and parking lot near the intersection of Surf Drive and Shore Avenue. The structures are in a deteriorated condition.

23. Low concrete curb fronted by mortared stone revetment at east end of parking lot.

24. Concrete-capped steel pile bulkhead, 175 feet long, with mortared riprap facing at east end of parking lot. Top of wall is at El. 9.0 feet M.L.W., the riprap at El. 7.0 feet M.L.W. Wall built in 1936 by the State and is in good condition.

25. Stone mound about 350 feet long in good condition.

26. Remains of concrete wall and dumped riprap about 150 feet long.

27. Stone groin in good condition with timber bulkhead extending landward.

28. Stone mound partly mortared, partly dry, about 200 feet long fronted alternately by three short stone groins in poor condition and three shorter timber groins.

29. Adjacent and abutting concrete walls in good condition, about 570 feet in total length.

30. Ten short concrete groins fronting westerly 170 feet of walls described in 29 above.

31. Row of boulders followed alternately by concrete and stone walls approximately 400 feet long. In good condition.

32. West jetty of mortared stone construction at Falmouth Harbor approximately 450 feet long with top elevation of 7.0 feet and side slopes of 1 on 1.5. Construction of the jetty by the Massachusetts Department of Public Works was completed in 1909. Since that time, maintenance and repairs have been made regularly by the State with the last contract for jetty repairs in 1952. Good condition.

33. East jetty of dry stone construction at Falmouth Harbor 150 feet long with top elevation about 7.0 feet. Construction of the jetty was completed in 1909 by the Massachusetts Department of Public Works. The jetty is in fair condition.

34. Mortared stone revetment running easterly from inshore end of east jetty. The first 300 feet of the revetment was constructed with a top elevation of 7.0 feet M.L.W., top width of three feet and side slopes of 1 on 1½ in 1939 by the Mass. Department of Public Works. Structure in good condition. An additional length of approximately 100 feet was added to the structure later. The structure protects a motel on the beach.

35. Dumped riprap along 680 feet of the seaward edge of Grand Avenue.

36. Stone groin about 190 feet long extending from the beginning of the concrete wall near Vernon Avenue built in 1937. In poor condition.

37. Concrete wall with concrete spur groins and riprap revetment extending about 3,200 feet from the stone groin near Vernon Avenue easterly around the bluff to the stone groin near the Casino. The wall was originally constructed in 1914 by the Commonwealth of Massachusetts. Repairs and maintenance have been made periodically since that time. Part of the wall was constructed with a vertical face reinforced by buttresses, while a greater length is made up of monolithic blocks having a concave face. This portion of the wall ties into a third section which has a

vertical face. The elevation of the top of the wall varies from 5.0 to 8.6 feet above M.L.W. Along the center section of the wall are four (4) short concrete groins set 50 feet apart. Riprap revetment has been laid in front of the entire wall. In some sections this revetment has been displaced and scattered. A band of riprap was placed on the lower part of the slope of the bluff above and behind the wall for 150 feet at its west end and 550 feet at the east end. Repairs were made to the riprap in 1955 by the State. Condition of the riprap is generally good with some sections of it having been displaced by runoff erosion of the bluff.

38. Four stone groins. Three were rebuilt and one new one was constructed by the State in 1949. Their lengths from west to east were 225 feet, 190 feet, 150 feet and 200 feet, respectively. The groin west of the Casino was constructed on the site of a groin built in 1937 and the most easterly groin is on the site of a groin built in 1919. The groins were built during 1949 with top elevations of 6.5 feet above M.L.W. at the inner ends and 2.5 feet above M.L.W. at the outer ends, top widths of 5 feet, and side slopes of 1 on 1.5. The groins are in fair to good condition.

39. Riprap protection around the foundation of the Casino.

40. A vertical faced concrete retaining wall with a curved upper lip at the town beach extending from the east side of the Casino eastward for about 1,530 feet. It is bordered by a paved walk on its landward side. It has a top elevation of 9.5 feet. At its easterly terminus, it abuts another concrete wall which is on private property.

41. Vertical faced concrete walls partly fronted by riprap revetment along the private shore east of the town beach. The walls are in good condition.

42. Three stone groins. The westerly two groins are in poor condition, while the easterly one is tight and in good condition.

43. Wood pier about 120 feet long. In good condition.

44. Two stone jetties flank a 30" culvert which drains Little Pond. The west jetty is 175 feet long, and the east jetty is 80 feet long. Both have top elevations at their inner ends of 6.0 feet, but the top elevations on the outer ends are 2.0 and 5.0 feet for the west and east jetties, respectively. There are two stone groins to the east constructed at the same time as the jetties. They have lengths from east to west of 135 and 50 feet. All four structures have top widths of 5 feet and side slopes of 1 on 1.5. They were built by the State in 1955. They are in excellent condition.

45. The remains of a 250-foot long concrete wall. The wall is now tilted or destroyed and it is ineffective for shore protection.

46. A concrete wall about 250 feet long fronted by concrete revetment along its westerly 80 feet and stone riprap revetment for the remaining length. There are four short timber and concrete groins extending out from the wall. Except for the east end of the wall, the structures are in good condition.

47. A concrete wall about 120 feet long and in fair condition. It is fronted by riprap revetment and a groin (44) which extends out from its west end.

48. The remains of a timber bulkhead abutted and partially fronted by riprap revetment. The remains of two timber groins extend out from the bulkhead.

49. Two stone groins, each about 120 feet long, in good condition.

50. A row of riprap fronted by a row of wood piles in front of old house foundations.

51. The two stone jetties at the entrance to Great Pond were constructed by the State, the west jetty in 1935 and the east jetty at a later date. The original dimensions of the west jetty were as follows: Length, 340 feet; Top Elevation, 7.0 feet; Top Width, 5 feet; and Side Slopes of 1 on 1.5. In 1946 both jetties were rebuilt by the State to the following dimensions: Length, west jetty, 310 feet, east jetty, 180 feet; Top Elevations, 5.3 feet; Top Width, 5 feet, and Side Slopes of 1 on 1.5. In 1955 the east jetty was again rebuilt by the State to a length of 205 feet and a top elevation of 5.5 feet, the other dimensions remaining the same. Both jetties are in good condition.

52. Along the shore from the bridge at the Great Pond entrance, dumped riprap at the bridge abutment continues eastward for about 800 feet. About 250 feet east of the entrance, there is a concrete wall, 425 feet long, made up of 7-foot long precast concrete blocks set on a stone mound. The wall is along the edge of Ocean Avenue, behind the dumped riprap. It was built by the State in 1955, with a top elevation of 8.0 feet, and top and bottom widths of 1.5 feet and 4.0 feet. The wall is generally in fair condition. Several blocks are tilted out of line.

53. Four stone groins along the Acapesket Shore were built by the State in 1946. Their originally constructed dimensions were as follows:

a. Easterly Groin. Length 250 feet; top elevation 5.3 feet; top width 5 feet. This groin was extended 75 feet landward between 1946 and 1951.

b. Second Groin from the East. Length 125 feet, top elevations of 4.3 and 1.3 feet at the inner and outer ends, respectively. Top width 5 feet.

c. Two Westerly Groins. Same original length, top elevations and top width as b above. These two groins were rebuilt by the State in 1955 to a length of 80 feet, top width of 6 feet and top elevation of 4.0 feet.

Slopes of all groins are 1 on 1.5. They are in good condition.

54. A riprap mound about 470 feet long with a top elevation of 9.0 feet. There is a stone groin about 130 feet long in front of the mound. Both structures are in good condition.

55. Two wood bulkheads fronting private residences and property. The westerly bulkhead which is about 90 feet long is in fair condition. The easterly bulkhead which is about 180 feet long is in excellent condition. A wood groin about 30 feet long extends seaward from the east end of the shorter bulkhead. About 25 feet seaward of the longer bulkhead, there are rows of wood piling interlaced with dumped riprap.

56. A stone groin 50 feet long extending eastward from the inner end of the groin described in 53 above, and two stone jetties each 275 feet long at the entrance to Green Pond were built in 1952 by the State. The structures were built with a top width of 5 feet, a top elevation of 6.0 feet, and side slopes of 1 on 1.5. The groin has undergone some unraveling. The two jetties are in good condition.

57. An ell-shaped timber bulkhead extends from the north end of the east jetty at Green Pond, first northward for 60 feet, then eastward for 170 feet. The bulkhead is tipped towards the inlet due to the load of sand behind it.

58. A series of three stone mounds, 300, 150, and 80 feet long. The top elevation of the 300-foot mound is about 6.0 feet. The mounds are in good condition.

59. Three timber and concrete groins and two stone groins. The timber and concrete groins are set about 150 feet apart and extend about 50 feet seaward of the 300-foot long stone mound. The groins are in fair condition. The most westerly of the two stone groins extends

seaward for a length of 100 feet from the east end of the 150-foot long stone mound, while the other groin which is about 80 feet long is located 160 feet eastward. Both groins are in a deteriorated condition.

60. A row of old wood piles and the remains of a wood bulkhead are located between the two stone groins described in 59. The structures are in a very deteriorated condition.

61. Riprap is strewn and buried in two sections of the beach. The most easterly section may be the remains of an old groin.

62. Two stone mounds, one 130 feet long, the other 230 feet long, front residences and private property. The westerly mound was privately constructed in November 1961. About 100 feet of the 230-foot stone mound has recently been built to a higher elevation than the remainder which is only in fair condition.

63. Four stone groins extend seaward of stone mounds and riprap in the Davisville area, as follows:

a. A 90-foot long groin at the east end of the new stone mound described in 62 above is in excellent condition.

b. A stone groin, 70 feet long, at the west end of the 230-foot long mound described in 62 above, abuts a 50-foot long section of the mound which extends landward. The groin is in fair condition.

c. A stone groin, 50 feet long, at the east end of the stone mound described above is in good condition.

d. A stone groin, 60 feet long, located 80 feet east of the groin described in 63 c above, abuts riprap at its inner end and is in good condition.

64. A row of wood piles and riprap 100 feet long. This structure is in a deteriorated condition.

65. A stone mound, 80 feet long, in good condition.

66. A timber bulkhead about 240 feet long, in fair condition.

67. Five groins from west to east as follows:

a. A short pile-enclosed stone groin about 50 feet long in good condition.

b. A stone groin about 75 feet long in good condition.

c. A stone groin about 65 feet long in good condition.

d. A stone groin about 100 feet long in good condition.

e. A 40 by 30 foot long ell-shaped wood bulkhead and groin in fair condition.

68. A rough stone mound about 110 feet long.

69. A stone groin about 110 feet long and located along the Menauhant shore about 900 feet east of the entrance to Bournes Pond was built cooperatively by the Town and State in 1934 and was reshaped by the State in 1949. As-built dimensions of the groin were: Length, 175 feet; Top width, 5 feet; Top Elevation, 6.5 feet M.L.W.; and Side Slopes, 1 on 1½. The groin is in poor condition.

70. Two stone groins respectively located 1,200 feet and 1,550 feet east of the entrance to Bournes Pond were built by the State in 1949. The groins were originally built 125 feet long with top widths of 5 feet, top elevations of 6.5 feet at the inner end and 2.5 feet at the outer end, and side slopes of 1 on 1.5. The structures are in good condition.

71. The remains of a wood bulkhead and short wood groins. The bulkhead, originally 400 feet long, was built cooperatively by the Town and State in 1934.

72. Dumped riprap along the edge of Menauhant Road.

73. Two flanked, short timber groins in fair condition.

74. A stone groin about 125 feet long in good condition. It was built cooperatively by the Town and State in 1934. The groin was originally 150 feet long, had a top width of 5 feet, top elevation of 6.5 feet and side slopes of 1 on 1.5. It was rebuilt by the State in 1949.

75. A mortared stone mound about 200 feet long in fair condition.

76. A stone groin about 120 feet long in good condition. The groin was built in 1949 by the State to the same dimensions as the groins described in 70 above.

77. A deteriorated timber bulkhead fronted by riprap.

78. A stone groin about 190 feet long in good condition. The groin was built by the State in 1937 to a length of 200 feet, top width of 4 feet, top elevation of 6.5 feet, and side slopes of 1 on 1.5. The groin was rebuilt by the State in 1949.

79. A stone groin about 220 feet long in good condition. The groin was built prior to 1948 to a length of 220 feet, top width of 4 feet, top elevation of 6.5 feet at its inner end, 2.5 feet at its outer end, and side slopes of 1 on 1.5.

80. A stone jetty about 300 feet long in good condition. The jetty was built by the State in 1953 to a length of 300 feet, top width of 5.0 feet, top elevation of 6.0 feet, and side slopes of 1 on 1.5.

81. Three flanked stone groins each about 130 feet long are offshore at the Eel Pond entrance. The groins are in poor condition.

82. Two stone jetties at the entrance to Waquoit Bay. The west jetty is 900 feet long with two 100-foot spurs extending westward from its inshore end. It was originally constructed by the State in 1937 to a length of 550 feet, top width of 5.0 feet, top elevation of 7.0 feet, with a mound at its seaward end with top elevation of 11.0 feet. The west jetty was enlarged to its present length after 1937. The initial construction of the east jetty was accomplished cooperatively by the Town and State in 1918. The original structure consisted of a riprap jetty 450 feet long, combined with a 400-foot long timber bulkhead, half of which was on the inshore end of the jetty and the other half shoreward of the jetty. A riprap wall 300 feet long and several spur jetties were included in the same project. The top elevation of the jetty was 3.0 feet, while that of the bulkhead varied from 4.0 to 8.4 feet M.L.W. Modifications and repairs necessitated by storm damages and settlement were made to the original structure in 1920, 1923, 1926, 1928, 1935, and in 1953. In 1953, 850 feet of the present length of 1,300 feet were repaired by the State by the addition of riprap to give a top width of 5.0 feet, top elevation of 7.0 feet, and side slopes of 1 on 1.5.

83. Beach Fills. The shore of the study area has been artificially nourished by placement of sand fill at several sections in recent years. Table G-1, below, shows known beach fills placed since 1926. The table indicates the year the work was accomplished, the agency doing the work, the section of the shore improved, and a brief description of the work.

76. A stone groin about 120 feet long in good condition. The groin was built in 1949 by the State to the same dimensions as the groins described in 70 above.

77. A deteriorated timber bulkhead fronted by riprap.

78. A stone groin about 190 feet long in good condition. The groin was built by the State in 1937 to a length of 200 feet, top width of 4 feet, top elevation of 6.5 feet, and side slopes of 1 on 1.5. The groin was rebuilt by the State in 1949.

79. A stone groin about 220 feet long in good condition. The groin was built prior to 1948 to a length of 220 feet, top width of 4 feet, top elevation of 6.5 feet at its inner end, 2.5 feet at its outer end, and side slopes of 1 on 1.5.

80. A stone jetty about 300 feet long in good condition. The jetty was built by the State in 1953 to a length of 300 feet, top width of 5.0 feet, top elevation of 6.0 feet, and side slopes of 1 on 1.5.

81. Three flanked stone groins each about 130 feet long are offshore at the Eel Pond entrance. The groins are in poor condition.

82. Two stone jetties at the entrance to Waquoit Bay. The west jetty is 900 feet long with two 100-foot spurs extending westward from its inshore end. It was originally constructed by the State in 1937 to a length of 550 feet, top width of 5.0 feet, top elevation of 7.0 feet, with a mound at its seaward end with top elevation of 11.0 feet. The west jetty was enlarged to its present length after 1937. The initial construction of the east jetty was accomplished cooperatively by the Town and State in 1918. The original structure consisted of a riprap jetty 450 feet long, combined with a 400-foot long timber bulkhead, half of which was on the inshore end of the jetty and the other half shoreward of the jetty. A riprap wall 300 feet long and several spur jetties were included in the same project. The top elevation of the jetty was 3.0 feet, while that of the bulkhead varied from 4.0 to 8.4 feet M.L.W. Modifications and repairs necessitated by storm damages and settlement were made to the original structure in 1920, 1923, 1926, 1928, 1935, and in 1953. In 1953, 850 feet of the present length of 1,300 feet were repaired by the State by the addition of riprap to give a top width of 5.0 feet, top elevation of 7.0 feet, and side slopes of 1 on 1.5.

83. Beach Fills. The shore of the study area has been artificially nourished by placement of sand fill at several sections in recent years. Table G-1, below, shows known beach fills placed since 1926. The table indicates the year the work was accomplished, the agency doing the work, the section of the shore improved, and a brief description of the work.

TABLE G-1

BEACH FILLS

Date of Fill	Agency	Section or Area	Description of Work
1926	State	Shore west of Falmouth Harbor entrance	6,500 cubic yards of sand dredged from entrance placed on beach west of west jetty.
1952	State	Shore west of Falmouth Harbor entrance	Sand dredged from Falmouth Harbor placed on beach west of entrance.
1946	State	Falmouth Heights	Sand dredged from Falmouth Harbor entrance placed on shore east of entrance.
1957	Corps of Engineers	Falmouth Heights	119,430 cubic yards of sand dredged from Falmouth Harbor placed on 1,650 ft. of beach at Falmouth Heights. The width of beach fill was specified as 120 ft., with a top elevation of 4.0 ft. M.L.W.
1955	State	Maravista	Sand fill placed along 440 ft. of shore west of and 200 ft. east of the Little Pond jetties and along 60 ft. of shore at street end west of the most easterly groin described in 44, above. Top elevation of sand fill, which was 40 - 100 ft. in width, was from 5.5 to 5.0 ft. M.L.W. with slope of 1 on 10 thereon.
1935	State	Acapesket	Sand fill dredged from Great Pond placed on shore immediately east of Great Pond entrance.
1953	State	Acapesket	Sand fill dredged from Green Pond entrance placed on shore west of jetties.
1953	State	Menauhant	Sand fill placed between west jetty at Eel Pond entrance and groin 400 ft. to west. Fill obtained from sand spit north of jetty and placed at top elevation of 5.0 ft. M.L.W. for 100-ft. width sloping to foreshore bottom on 1 on 10.
1956	State	Menauhant	Sand fill dredged from Eel Pond placed along 1200 ft. of shore between points approx. 200 and 1400 ft. west of the groin numbered 76 on Plate No. 4

APPENDIX H

BEACH PROFILES

1. General. - Twenty-four beach profiles were surveyed during 1961 at selected locations throughout the study area. They extended over barrier beaches, low shore roads or seaward of the toes of bluffs or protective structures. Six of the profiles at Falmouth Heights had lengths of 300 to 500 feet and were run out to depths of 6 to 9 feet. The other 18 profiles were longer. They were run to depths of at least 25 feet and generally 30 or more feet with lengths of some exceeding one mile. Profiles are shown on Plates 2, 3 and 4 and plots of profiles are shown on Plates 5 through 8. Beach slopes were determined from the plots and they are shown in the following tabulation. Slopes are given from the landward to the seaward ends of the profiles thus, 1/10 (8 to -5) which reads one vertical over ten horizontal from 8 feet above to 5 feet below the plane of mean low water. Slopes flatter than 1/100 are listed as level.

Beach Profiles

No.	Location	Slopes
1.	Washburn Island	1/10(8 to -5); $\frac{1}{61}$ (-5 to -10); level below -10.
2.	Washburn Island	Level berm (6.5); $\frac{1}{12}$ (6 to -4); level (-4 to -7); 1/60(-7 to -15); level below -15.
3.	Menauhant	1/3(6 to -3); $\frac{1}{76}$ (-3 to -7); level below -7.
4.	Davisville	Level @ wall (2); $\frac{1}{44}$ (2 to -4); level below -4.
5.	Davisville	1/9(3 to -4); $\frac{1}{63}$ (-4 to -8); level below -8.
6.	Acapesket	1/16(0.0 to -5); level (-5 to -6); $\frac{1}{27}$ (-6 to -9.5); level below -9.5.
7.	Mara Vista	Level berm (5); $\frac{1}{6}$ (5 to -3); $\frac{1}{40}$ (-3 to -10); level below -10.
8.	Mara Vista	1/11(6 to -3); $\frac{1}{26}$ (-3 to -6); $\frac{1}{90}$ (-6 to -10); level below -10.

Beach Profiles (Continued)

No.	Location	Slopes
9.	Falmouth Heights	1/6 (6 to -6); level below -6.
10.	Falmouth Heights	1/12 (7 to -4); $\frac{1}{40}$ (-4 to -7).
11.	Falmouth Heights	$\frac{1}{22}$ (7 to 3); 1/8 (3 to -4); $\frac{1}{42}$ (-4 to -8).
12.	Falmouth Heights	$\frac{1}{46}$ (7 to 5); 1/8 (5 to -6); level below -6.
13.	Falmouth Heights	Level berm (5); 1/20 (5 to -7).
14.	Falmouth Heights	$\frac{1}{20}$ (9 to -9).
15.	Falmouth Heights	1/20 (6 to -9).
16.	Falmouth Heights	1/28 (2 to -10); level below -10.
17.	Between Falmouth Harbor and Falmouth Beach	1/12 (8 to -7); level below -7.
18.	Falmouth Beach	1/14 (8 to -4); $\frac{1}{63}$ (-4 to -10.5); level below -10.5.
19.	Falmouth Beach	Level berm (6.5); 1/13 (6.5 to -2); 1/60 (-2 to -8); level below -8.
20.	Falmouth Beach	Level berm (6.5); 1/15 (6.5 to -3); level below -3.
21.	Falmouth Beach	1/10 (6 to -6.5); level below -6.5.
22.	Between Nobska Point and Falmouth Beach	1/7 (8 to 1); $\frac{1}{40}$ (1 to -4); 1/10 (-4 to -11); level below -11.
23.	Between Nobska Point and Falmouth Beach	Level berm (6); $\frac{1}{22}$ (6 to -14); level (-14); 1/36 (-14 to -27); level below -27.
24.	Nobska Point	1/20 (-2 to -28)

2. Due to the lack of prior profiles, seasonal changes could not be determined. The profiles indicate the following:

Washburn Island. - A beach berm exists at elevation 6.5 feet. Seaward of this, the beach slopes are 1/10 to 1/12 down to depths of 4 to 5 feet and they level off below these depths.

Menauhant. - The beach slopes steeply (1/3) from above high water to a depth of 3 feet and then levels off.

Davisville. - The beach is steeper at its west end. From above high water to depths of 3 to 4 feet, the beach slope is $\frac{1}{44}$ at its east and 1/9 at its west end. Slopes level off at about the 4-foot depth at the east end and 8 feet at the west end.

Acapesket. - Seaward of the low water line to the 5-foot depth, the slope is about 1/16 and it levels off at about the 10-foot depth.

Mara Vista. - The east end of the beach is steeper from above high water to the 3-foot depth (1/6 at east end and 1/11 at west end), and it levels off at about the 10-foot depth.

Falmouth Heights. - A wide berm exists at elevations 5 or 6 feet at the public bathing beach east of the Casino and it decreases eastward and westward. The beach along and east of this beach has slopes seaward of the berm of 1/6 to 1/12 down to depths of 6 to 8 feet where it levels off. To the west where there is little or no berm, the beach slopes seaward at 1/20 to 1/28 and levels off at a depth of 10 feet.

Between Falmouth Harbor and Falmouth Beach. - There is no berm. The shore slopes at 1/12 down to a 7-foot depth and levels off.

Falmouth Beach. - The beach berm at elevation 6.5 is wider along the east half. The beach slopes seaward from the berm down to depths of 2 to 4 feet at 1/15 to 1/10 and levels off at depths of 3 to 10 feet, the greater depths at the east end.

Between Nobska Point and Falmouth Beach. - At the west end, there is a berm at elevation 6.0. The beach slopes seaward, in steps, steeper at its east end (1/7 to 1/10 at Profile 22 and 1/22 to 1/36 at Profile 23). Slopes level off at the 11-foot depth at the east end and the 27-foot depth at the west end.

Nobska Point. - No berm. The shore slopes uniformly downward at 1/20 to the 28-foot depth.

APPENDIX I

ESTIMATES OF COSTS OF IMPROVEMENTS

1. General. - A useful life of 50 years has been used in determining amortization charges. An annual interest rate of 3.5 percent has been used for the annual charges which are all non-Federal. Maintenance requirements for beach fills are based on maximum rates of loss determined from past shore recession with a minimum rate of loss of one foot per year. A shore recession of two feet per year was assumed for the fill area at Falmouth Heights. It has been assumed that groins and jetties will reduce the rates of loss by 50 percent. Annual maintenance costs of jetties, groins, revetments and seawalls have been estimated as one percent of the first cost of construction.

2. Shore Between Nobska Point and Falmouth Beach. - The plan of protection consists of a stone mound and slope protection for the bluffs in this area. Costs have been developed per linear foot of improvements.

a. First Cost Per Linear Foot

Mound and slope protection, 9.3 tons stone @ $7.00	$73.00 *
Engineering and Design	2.00
Subtotal	$75.00
Supervision and Administration	6.00
Total First Cost	$81.00

*Includes Contingencies

b. Annual Charges Per Linear Foot

Interest - 0.035 x $81.00	$2.80
Amortization 0.00763 x $81.00	0.60
Maintenance	0.60
Total Annual Charges	$4.00

3. Falmouth Heights (West End). - The plan of protection and improvement consists of beach widening by direct placement of sand fill, extension of the East Jetty at Falmouth Inner Harbor, and enlargement and extension of one groin.

a. Total First Cost

Jetty extension - 1,700 tons stone @ $12.00		$23,400 *
Groin enlargement 1,000 tons stone @ $12.00		13,600 *
Beach fill - 25,000 cu. yds. @ $ 1.50		43,100 *
	Subtotal	$80,100
Engineering & Design		2,400
	Subtotal	$82,500
Supervision & Administration		6,500
	Total First Cost	$89,000

* Includes Contingencies

b. Total Annual Charges

Interest - 0.035 x $89,000	$ 3,100
Amortization 0.00763 x $89,000	700
Maintenance	
Jetty repairs - 17 tons stone @ $12.00	200
Groin repairs - 10 tons stone @ $12.00	100
Beach fill - 1,200 cu. yds. @ $ 1.50	1,800
Total Annual Charges	$ 5,900

4. Falmouth Heights (Central Portion). - The plan of protection consists of placement of riprap revetment fronting an existing seawall and stone slope protection on the bluff landward of the wall.

a. Total First Cost

Revetment,	5,200 tons stone @ $6.00	$35,700 *
Slope protection,	1,100 tons stone @ $6.00	7,500 *
	Subtotal	$43,200
Engineering & Design		1,300
	Subtotal	$44,500
Supervision & Administration		3,500
	Total First Cost	$48,000

*Includes Contingencies

b. Total Annual Charges

Interest 0.035 x $48,000		$ 1,700
Amortization 0.00763 x $48,000		370
Maintenance		
Revetment,	52 tons @ $8.00	420
Slope protection,	11 tons @ $8.00	90
	Total Annual Charges	$ 2,580

5. Mara Vista. - The plan of protection consists of construction of 1,900 feet of concrete walls on the seaward side of Menauhant Road.

a. Total First Cost

Concrete walls, 1,900 feet long, 520 cu. yds. @ $40.00		$24,000 *
Engineering & Design		2,000
	Subtotal	$26,000
Supervision & Administration		2,000
	Total First Cost	$28,000

*Includes Contingencies

b. Total Annual Charges

Interest 0.035 x $28,000	$ 1,000
Amortization 0.00763 x $28,000	200
Maintenance, wall repairs	300
Total Annual Charges	$ 1,500

6. Acapesket. - The plan of protection and improvement consists of beach widening by direct placement of sand fill, and the enlargement and extension of four groins.

a. Total First Cost

Groins, 11,600 tons stone @ $8.00		$106,500 *
Beach fill, 100,000 cu. yds. @ $1.25		143,500
	Subtotal	$250,000
Engineering & Design		8,000
	Subtotal	$258,000
Supervision & Administration		20,000
	Total First Cost	$278,000

*Includes Contingencies

b. Total Annual Charges

Interest 0.035 x $278,000	$ 9,700
Amortization 0.00763 x $278,000	2,100
Maintenance	
Groin repairs, 116 tons stone @ $10.00	1,200
Beach fill, 1,700 cu. yds. @ $ 1.50	2,600
Total Annual Charges	$15,600

7. Davisville. - The plan of protection and improvement consists of beach widening by direct placement of sand fill and construction of one new jetty and two new groins.

a. Total First Cost

Jetty and two groins,	9,700 tons stone @ $8.00	$ 89,300 *
Beach fill,	60,000 cu. yds. @ $1.40	96,700 *
	Subtotal	$186,000
Engineering & Design		6,000
	Subtotal	$192,000
Supervision & Administration		15,000
	Total First Cost	$207,000

*Includes Contingencies

b. Total Annual Charges

Interest 0.035 x $207,000		$ 7,250
Amortization 0.00763 x $207,000		1,580
Maintenance		
Jetty and groins repairs,	97 tons stone @ $10.00	970
Beach fill,	1,200 cu. yds. @ $ 1.50	1,800
	Total Annual Charges	$11,600

8. Menauhant. - The plan of protection and improvement consists of beach widening by direct placement of sand fill, the enlargement of three groins, and the construction of 1,500 feet of concrete wall on the seaward side of Menauhant Road.

a. Total First Cost

Groins,	3,100 tons stone @ $12.00	$ 42,200 *
Beach fill,	74,000 cu. yds. @ $ 1.35	114,100 *
Concrete wall,1500 ft. long,	420 cu. yds. concrete @ $40.00	19,100 *
	Subtotal	$175,400
Engineering & Design		5,300
	Subtotal	$180,700
Supervision & Administration		14,300
	Total First Cost	$195,000

*Includes Contingencies

b. Total Annual Charges

Interest 0.035 x $195,000		$ 6,800
Amortization 0.00763 x $195,000		1,400
Maintenance		
Groin repairs,	31 tons stone @ $12.00	400
Beach fill,	1,800 cu. yds. @ $ 1.50	2,700
Wall repairs		200
	Total Annual Charges	$11,500

APPENDIX J

BEACH EROSION CONTROL REPORT ON COOPERATIVE STUDY OF FALMOUTH, MASSACHUSETTS

INFORMATION CALLED FOR BY SENATE RESOLUTION 148, 85TH CONGRESS, ADOPTED 28 JANUARY 1958

1. The study covers the south or Vineyard Sound shore of Falmouth, Massachusetts, between Nobska Point and Waquoit Bay. The problem consists of erosion of bluffs and beaches and storm damages to low shore roads and coastal development from wave attack. The shore is exposed to wave attack from the Atlantic Ocean across Vineyard and Nantucket Sounds through limited openings between offshore islands. The mean range of tide varies from 1.1 to 1.5 feet. The highest tide of record of 12.7 feet above mean low water occurred at Falmouth Heights during 14-15 September 1944.

2. Improvements Considered. - Plans were developed for protection and improvement of shore areas as follows:

a. Between Nobska Point and Falmouth Beach. - Construct stone mounds or stone revetment wherever needed for bluff protection.

b. Between Falmouth Inner Harbor and Bluffs at Falmouth Heights. - Widen 1,000 feet of beach by direct placement of sand fill, lengthen Falmouth Harbor East Jetty to 250-foot length, enlarge and lengthen existing groin to 250-foot length.

c. Falmouth Heights Bluffs. - Place additional riprap revetment along the toe of approximately 1,450 feet of wall, place stone revetment on approximately 750 feet of slope above the wall and control surface runoff wherever needed.

d. Mara Vista. - Construct low walls, approximately 1,900 feet long along the seaward side of the shore road.

e. Acapesket. - Widen 1,300 feet of beach by direct placement of sand fill, enlarge and lengthen four (4) existing groins to 345 to 510-foot lengths.

f. Davisville. - Widen 1,500 feet of beach by direct placement of sand fill, construct a jetty 530 feet long and two groins 340 and 510 feet long.

g. Menauhant. - Widen 1,600 feet of beach by direct placement of sand fill, enlarge and lengthen three (3) existing groins to 240 to 280 foot lengths.

In addition, general methods of protection and improvement were considered for other areas which did not merit development of detailed plans. These methods consisted of maintenance of existing protective works, construction of additional similar structures, reconstruction or relocation of low shore roads at higher elevations, placement of stockpiles of sand along the shore to nourish beaches and location of future developments at a high enough elevation or sufficiently landward to minimize damaging wave attack. A number of low barrier bars fronting ponds are considered generally unsuitable for residential development, due to their low elevation and vulnerability to overtopping and damages during severe storms and hurricanes. Complete protection of low areas by high seawalls or other barriers is not warranted by the limited developments which would benefit.

3. Conclusions and Recommendations. - Due to the adequacy of public beach areas for present recreational use, the lack of information to indicate the need for additional area for prospective use, the small value of benefits to be derived from protecting public roads and public lands or the private ownership and consequent private benefits to be derived from protecting private property, the public interest, as required by Public Law 826, 84th Congress, is insufficient to warrant Federal participation in the cost of the projects considered. Therefore, it was recommended that no projects be adopted by the United States for the protection or improvement of the shores of Falmouth, Massachusetts. It was further recommended that protective measures which may be undertaken by local interests, based upon their determination of economic justification, be accomplished in accordance with plans and methods considered in the study. Estimated first costs of considered improvements, all non-Federal, are listed as follows:

Location	Improvement	Estimated First Cost
Between Nobska Point and Falmouth Beach	Stone mound and slope protection	$81.00 per linear foot
Falmouth Heights (West End)	Groin and jetty enlargement and beach fill	89,000
Falmouth Heights (Central Portion)	Stone revetment and slope protection	48,000
Mara Vista	Concrete wall	28,000
Acapesket	Enlargement of 4 groins and beach fill	278,000
Davisville	Construction of jetty, 2 groins and beach fill	207,000
Menauhant	Enlargement of 3 groins, beach fill and concrete wall	195,000

4. Discussion. - The economic justification for construction of the considered projects has not been determined. Benefits were not evaluated since benefits to be derived are principally private and not of a type to make the improvements eligible for Federal aid under existing Federal policy. Changing the economic life of the projects would not change the findings of the study in so far as they pertain to eligibility for Federal aid.

APPENDIX K

DESIGN ANALYSIS

1. Design Tide. - The design tide is the highest tide which it is estimated occurs in the study area on an average once a year. Estimate of the height of the design tide was based on observed tidal heights of comparatively short duration at locations within the study area and of longer duration at Newport, Rhode Island and Boston, Massachusetts, as described in Appendix E. The design tide of 3.0 feet above mean high water was estimated as an average of the tides of record at Boston and Newport.

2. Design Wave. - The height of design wave used for structures is the highest wave which can occur at the structure at the time of design tide. Determination was based on the limitations imposed by fetch and wind speeds and also by depths of water at the structure. Water depths limited the possible wave heights more than fetch and wind speed. Therefore, design wave height was computed using the solitary wave formula $H = \frac{d}{1.28}$ where H is the wave height and d is the depth of water at time of design tide. The following conditions of probable occurrence would result in the highest waves in the study area generated across Nantucket and Vineyard Sounds:

Wind	ESE	38 m.p.h (statute)
Fetch		32.6 miles "
Depth		48 feet
Time		7 hours

Wave generation across shallow water, based on the above conditions, is estimated to result in a wave height of 11.1 feet and a wave period of 4.6 seconds. Maximum wave heights, based on the depths of water encountered at the structures, are tabulated below:

Depth Water (Feet MLW)	Design Depth (d)* (Feet)	Wave Height (H) (Feet)
7.5	11.8	9.2
6.0	10.3	8.0
5.2	9.5	7.4
3.0	7.3	5.7
+1.0	3.3	2.6

* Depth water plus mean range of tide (1.3) plus design tide (3.0).

3. Weights and Slopes of Stone Structures. - The minimum weights and slopes of armor stones in structures are determined from the formula

$$W = \frac{W_r \, H^3}{K_D \, (S_r - 1)^3 \, \text{Cot} \, \alpha}$$

where W = weight of stone in pounds

W_r = unit weight of stone in pounds/ cu. ft.

K_D = a coefficient; 2.0 for the heads of structures and 2.5 for the trunks

S_r = specific gravity W_r/W_w = $\frac{\text{unit weight stone}}{\text{unit weight of water}}$

α = angle of slope to the horizontal

H = wave height at structure

Minimum weights of armor stones and slopes were determined as tabulated below:

Wave Height (Feet)	Slope	K D	Minimum Weight of Stone (lbs)	Section of Study Area
9.2	1 on 2	2.0	8200	Falmouth Heights (West End)
8.0	1 on 1.5	2.0	7200	" " " Davisville Menauhant
7.4	1 on 1.5	2.0	5700	Acapesket
5.7	1 on 1.5	2.5	2080	Entire
2.6	1 on 1.5	2.0	245	Falmouth Heights (Central Part)

The core or bedding stone immediately beneath the armor stone was designed to contain assorted sizes with at least one-half the stone having weights equal to 10 per cent of the armor stone weight and the remainder in smaller quarry run sizes. The top width of jetties and groins and the thickness of armor stone in revetments are at least

twice the dimension of the side of a cube of stone having the specified weight of the armor stone. A lesser thickness of armor stone is necessitated in some instances of groin or jetty design due to the limited size of the structures.

4. Wave Runup. - The wave runup was computed for the proposed revetment at Falmouth Heights using the composite slope method. Runup was determined as 4.0 feet which superimposed on the design tide of 4.3 feet results in a top elevation of runup of 8.3 feet.

APPENDIX L

REPORT OF THE UNITED STATES FISH AND WILDLIFE SERVICE

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
59 Temple Place
Boston 11, Massachusetts

March 4, 1963

Division Engineer
New England Division
U. S. Army Corps of Engineers
424 Trapelo Road
Waltham 54, Massachusetts

Dear Sir:

This is our conservation and development report on the beach erosion control plans for Falmouth, Massachusetts, as described in the letter dated September 12, 1962, and accompanying maps, from the Deputy Division Engineer. This report was prepared under the authority of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.), in cooperation with the Massachusetts Division of Marine Fisheries and Division of Fisheries and Game, who indicated their concurrence by letters dated December 18, 1962 and December 19, 1962, respectively.

We understand that there are several methods under consideration for correction of beach erosion. The plans under consideration are:

1. Between Nobska Point and Falmouth Beach: Construct stone mounds or stone revetments wherever needed for bluff protection.

2. Between Falmouth Inner Harbor and Bluffs at Falmouth Heights: Widen 1,000 feet of beach by direct placement of sand fill, lengthen Falmouth Harbor East Jetty to 250-foot length,. enlarge and lengthen existing groin to 250-foot length.

3. Falmouth Heights Bluffs: Place additional riprap revetment along the toe of approximately 1,450 feet of wall, place stone revetment on approximately 750 feet of slope above the wall and control surface runoff wherever needed.

4. Mara Vista: Construct low walls, approximately 1,900 feet long along the seaward side of the shore road.

5. Acapesket: Widen 1,300 feet of beach by direct placement of sand fill, enlarge and lengthen four existing groins to 345 to 510-foot lengths.

6. Davisville: Widen 1,500 feet of beach by direct placement of sand fill, construct a jetty 530 feet long and two groins 340 and 510 feet long.

7. Menauhant: Widen 1,600 feet of beach by direct placement of sand fill, enlarge and lengthen three existing groins to 240 to 280-foot lengths.

The project works would be situated in areas of biological significance. Quahogs, soft-shelled clams, and bay scallops are produced in the salt-water ponds and support a commercial and recreational shellfishery of considerable significance. Finfish resources in the area support a highly valued sportfishery; the species of primary importance are striped bass, bluefish, winter flounder, northern scup, and tautog. The existing groins or jetties which will be affected by the project will provide 24,000 fisherman-days annually, having a value of $36,000. Waterfowl use of the salt ponds is moderate during migration and wintering periods; the black duck and Canada goose are common migrants and winter residents. Other waterfowl species and shorebirds use the ponds in varying concentrations.

In Falmouth Inner Harbor quahogs are produced on about seven acres of underwater lands. Because of heavy pollution, shellfishing is not permitted. However, seed and adult quahogs are transplanted to unpolluted waters from this area. The 10-year average annual quahog seed stock transplanting program has been 1,000 bushels; up to 4,000 bushels have been transplanted per year under a State-operated program. The town received from $2 to $12 a bushel for transplant stock, depending upon graded sizes. The present town transplanting program has a potential for expansion if additional funds are appropriated. Limited scallop and soft-shelled clam resources are present but are not utilized because of pollution.

There are quahog, scallop, and soft-shelled clam resources in Great Pond. (See plate II). The town shellfish officer estimates that between $50,000 and $60,000 worth of shellfish were harvested from the pond in 1961. Scallops can be taken only by family-permit holders; quahogs and soft-shells can be taken by both recreational and commercial shellfishermen.

Bournes Pond provides an estimated $25,000 to $30,000 worth of shellfish annually. Quahogs, soft-shelled clams, and scallops are harvested primarily by recreational diggers. Commercial shellfishing is limited. Excessive shoaling and unstable bottom have eliminated a sizeable portion of the lower pond for shellfish production.

Dredging offshore or from inland borrow pits to obtain beach fill would not have any significant effect upon fish and wildlife resources. Dredging from the ponds behind the beaches would be damaging to the resources if fill were removed from certain areas; if dredging were limited to areas as described below and as shown on attached plates I, II, and III, it would enhance habitat conditions and improve the potential for utilization of the finfishery and shellfishery.

If it becomes necessary to dredge in Falmouth Inner Harbor, beach fill could be dredged in the lower harbor to an east-west line, 1,100 feet from the town beach, without causing significant damages to the shellfish habitat or resources. (See plate I). The town should be notified 90 days in advance of dredging operations to permit removal of quahogs for transplanting. Dredging should be done between October 1 and January 1 to minimize siltation damages to spawning shellfish and winter flounder in this and any of the ponds of significance to shellfish or waterfowl which are discussed below.

It would be important, also, to insure that channel dredging in each pond entrance be done in a way that will provide a continuous channel through the offshore shoaling, thus permitting unimpeded interchange of waters between the ponds and the sound.

If dredging becomes necessary in Great Pond, damages to shellfish habitat would be insignificant provided it conforms to patterns described in plate II. The marsh islands near the pond entrance should be avoided. Their continued presence contributes to maintenance of nutrient supplies in the pond area. The town should be notified 90 days in advance of dredging operations to permit removal of quahogs for transplanting to other areas of the same pond. Conditions would be improved for utilization of the fishery for striped bass, bluefish, winter flounder, summer flounder, scup, and tautog.

Dredging would cause no significant damage to shellfish habitat in Bournes Pond if it is done in the area shown on plate III. Dredging would eliminate the shoal, allow for a greater interchange of waters between the Sound and the pond, and possibly provide improved habitat for quahogs and scallops.

There will be no significant effect upon shellfish habitat if dredging is done in Green Pond. Marsh habitat of special value to shorebirds however. would be destroyed if the southwestern and western shores of Green Pond were dredged; these areas should be preserved. Spoil which is excess to that needed for construction should not be deposited on marsh habitat.

The construction of stone mounds or stone revetments and offshore dredging will have no detrimental effect upon fish and wildlife habitat or resources. The lengthening of existing groins and jetties, and construction of new groins and jetties, will have no harmful effects upon the resources, and will tend to stabilize the beach-sand littoral drift and stabilize bottom conditions within the ponds, thus possibly extending shellfish and waterfowl habitat. Lengthened groins and jetties would provide an estimated 63,000 fisherman-days per year, a net increase of 39,000 fisherman-days, representing a benefit of $58,500.

There is an opportunity to further increase the sportfishery benefits of the project. This would involve (1) modification of the groins and jetties to hold the top elevation to within a six-inch vertical variation and chink gaps in the top surface to provide a safe walking surface, and (2) provision of adequate parking facilities. Due to access possibilities and use-potential, this would be most applicable on the groins and jetties listed below. We have numbered the groins and jetties for easy reference:

Structure No.	Designation, location
1	Falmouth Harbor east jetty
2	Groin 1,200 feet east of Falmouth Harbor
3	Groin 1,000 feet west of Green Pond
4	Groin 1,400 feet east of Green Pond east jetty
5	Groin 1,700 feet east of Green Pond east jetty
6	Bournes Pond west jetty
7	Groin 2,100 feet west of Eel Pond entrance
8	Groin 1,450 feet west of Eel Pond entrance
9	Groin 750 feet west of Eel Pond entrance

There is potential for added fishing opportunities at the Falmouth Harbor east jetty and the groin located 1,200 feet east of Falmouth Harbor, structures numbers 1 and 2, respectively. Winter flounder and tautog are fished from both structures; bluefish and striped bass provide added fishing from the jetty. The town owns the land from which the groin and jetty extend seaward.

Groin number 3, 1,000 feet west of Green Pond and groins numbers 4 and 5, 1,400 feet and 1,700 feet, respectively, east of the Green Pond east jetty also offer potential for improved fishing opportunity. Groins numbers 4 and 5 extend seaward from town-owned land and fisherman access is possible from the land end. The Bournes Pond west jetty, number 6, would offer improved fishing opportunity for bluefish, striped bass, winter flounder, tautog, and northern scup. Because the landward end is on private property, fisherman access is gained from the beach.

The two groins, numbers 7 and 8, between Bournes Pond and Eel Pond, are accessible from town-owned beach. Access to groin number 9, 750 feet west of Eel Pond, can be gained from the abutting roadway.

It is estimated that the fisherman use would amount to an average of 85,000 fishermen days annually during the project life if the structures were modified as previously described, and if adequate parking facilities are provided. This is an increase of 22,000 fisherman-days annually over the with-the-project conditions. This benefit is valued at $33,000. Table 1 summarizes the average annual fisherman-days for each groin or jetty over the life of the project, without the project, with the project, and with the modified project, i.e. with parking areas and smooth surfaces on the jetties and groins.

Table 1. Estimated average annual fisherman use (fisherman-days)

Groin or jetty	Without the project	With the Project	With the Modified Project
1	6,900	12,400	16,800
2	500	7,200	9,700
3	700	13,500	18,100
4	0	5,500	7,400
5	0	5,500	7,400
6	0	5,000	6,700
7	5,500	3,000	4,000
8	3,700	3,500	4,700
9	6,900	7,400	10,200
Rounded	24,000	63,000	85,000

Parking area capacities needed are shown in table 2. Parking areas for two or more structures may be combined. They should be constructed on the land side of the road. Marsh areas should not be filled to provide parking areas if convenient parking facilities can be provided elsewhere.

Table 2. Parking area requirements

Groin or jetty	Number of cars
1	30
2	20
3	30
4	15
5	15
6	10
7	10
8	10
9	20

The implementation of the following recommendations will provide increased sport fishing opportunities and will minimize damages to the resources. In view of the fact that the increased benefits from the sportfishery would accrue to the public at large rather than to any identifiable segment of the public, the sport fishing facilities and the required parking facilities should be a non-reimbursable Federal cost of the project.

We recommend--

1. That necessary beach fill materials be obtained from Falmouth Inner Harbor as indicated on plate I; the town be notified 90 days prior to starting dredging activities to permit removal of quahog stocks from the dredge site.

2. That necessary beach fill materials be obtained from Great Pond as indicated on plate II; the marsh islands be avoided.

3. That the town be notified 90 days prior to dredging activities to permit removal of quahogs for transplanting elsewhere in Great Pond.

4. That dredging be done between October 1 and January 1 in any pond of indicated significance to shellfish or waterfowl.

5. That dredging activities in Bournes Pond be done in the area shown on plate III.

6. That dredging of the marshy area along the western and southwestern shores of Green Pond be avoided.

7. That groins and jetties listed above be constructed with the top elevations held to within a 6-inch vertical variation and to gaps in the top surface chinked to within a 6-inch opening to provide a safe walking surface for fishermen.

8. That adequate parking areas for fishermen be provided as described above.

R 4/15/63

9. That dredging necessary to obtain beach fill be done in such manner that the seaward end of each channel be dredged through the offshore shoaling at the pond entrances to provide a continuous channel.

10. That spoil which is in excess of that needed for construction not be deposited on marshlands.

11. That, if the project is recommended for Federal construction, the cost of providing parking areas and smooth surfaces on groins and jetties for sportfisherman-use be a non-reimbursable Federal cost of the project.

Sincerely yours,

John S. Gottschalk
Regional Director
Bureau of Sport Fisheries & Wildlife

John T. Gharrett
Regional Director
Bureau of Commercial Fisheries

We recommend --

1. That necessary beach fill materials be obtained from Falmouth Inner Harbor as indicated on Plate I; the town be notified 90 days prior to starting dredging activities to permit removal of quahog stocks from the dredge site.

2. That necessary beach fill materials be obtained from Great Pond as indicated on Plate II; the marsh islands be avoided.

3. That the town be notified 90 days prior to dredging activities to permit removal of quahogs for transplanting elsewhere in Great Pond.

4. That dredging be done between October 1 and January 1 in any pond of indicated significance to shellfish or waterfowl.

5. That dredging activities in Bournes Pond be done in the area shown on Plate III.

6. That groins and jetties listed above be constructed with the top elevations held to within a 6-inch vertical variation and to gaps in the top surface chinked to within a 6-inch opening to provide a safe walking surface for fishermen.

7. That adequate parking areas for fishermen be provided as described above.

8. That dredging necessary to obtain beach fill be done in such manner that the seaward end of each channel be dredged through the offshore shoaling at the pond entrances to provide a continuous channel.

9. That the cost of providing parking areas and smooth surfaces on groins and jetties for sportfisherman-use be a non-reimbursable Federal cost of the project.

Sincerely,

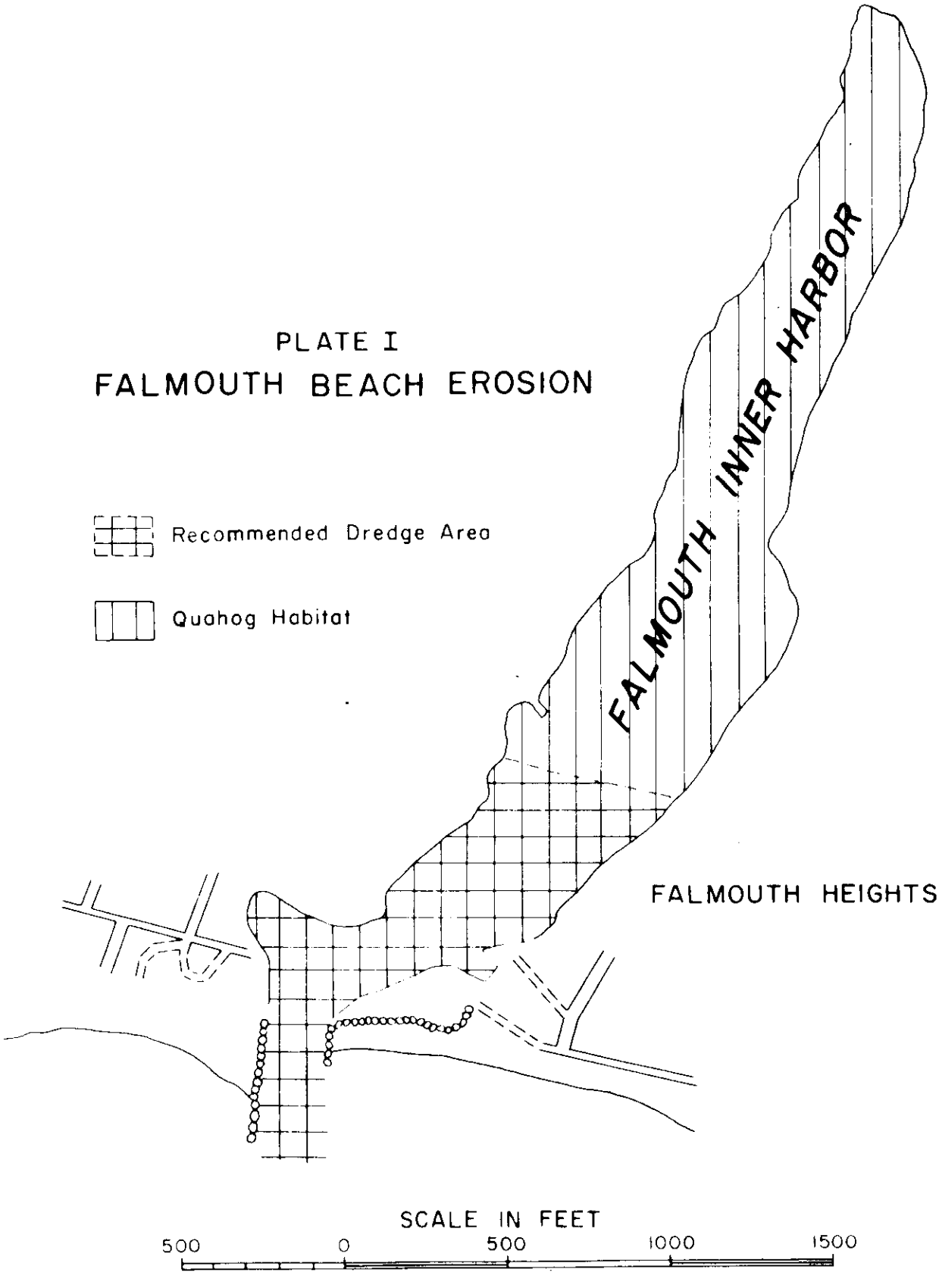


PLATE I
FALMOUTH BEACH EROSION
Recommended Dredge Area
Quahog Habitat
FALMOUTH INNER HARBOR
FALMOUTH HEIGHTS
SCALE IN FEET
500
0
500
1000
1500

PLATE II

FALMOUTH BEACH EROSION

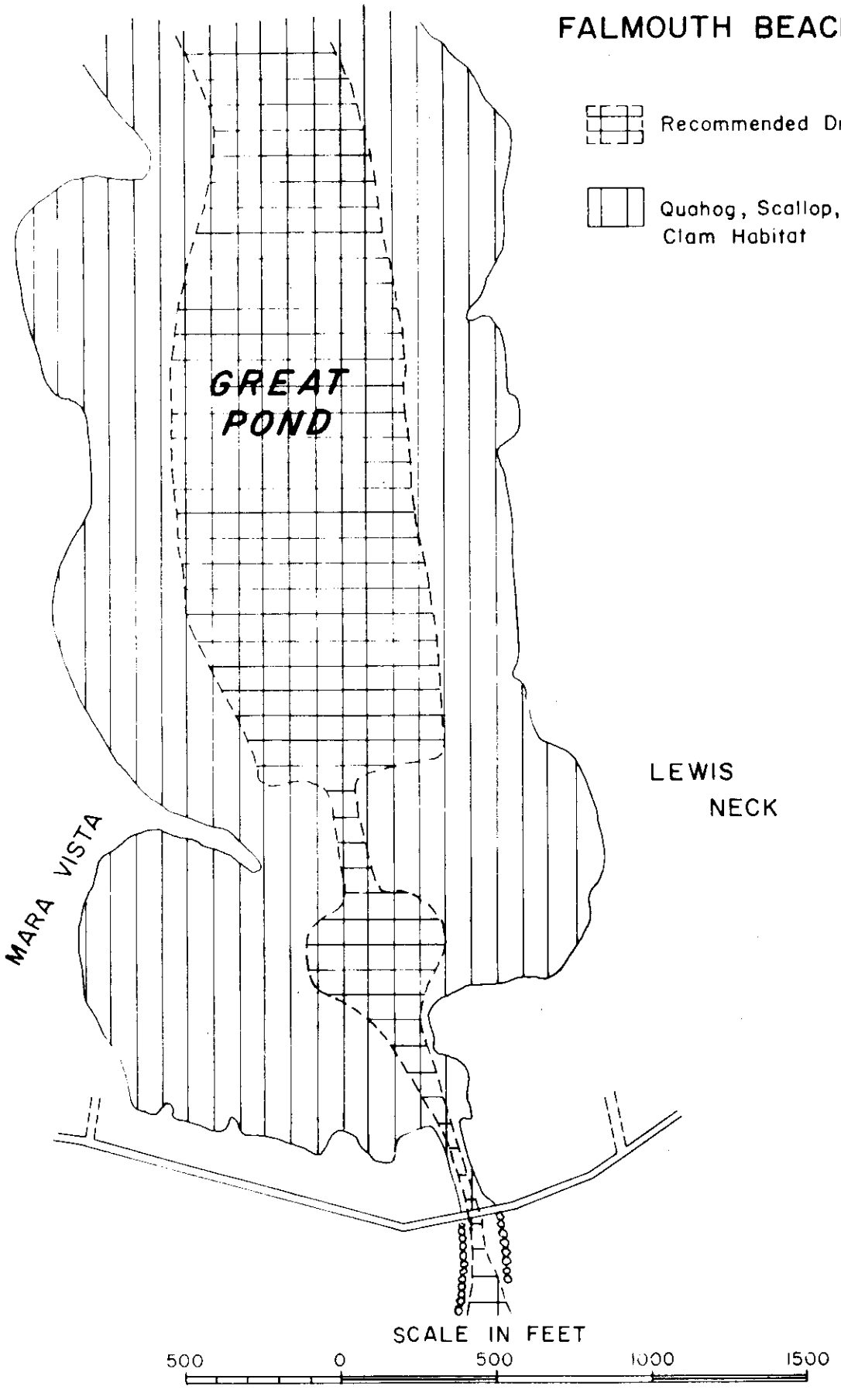
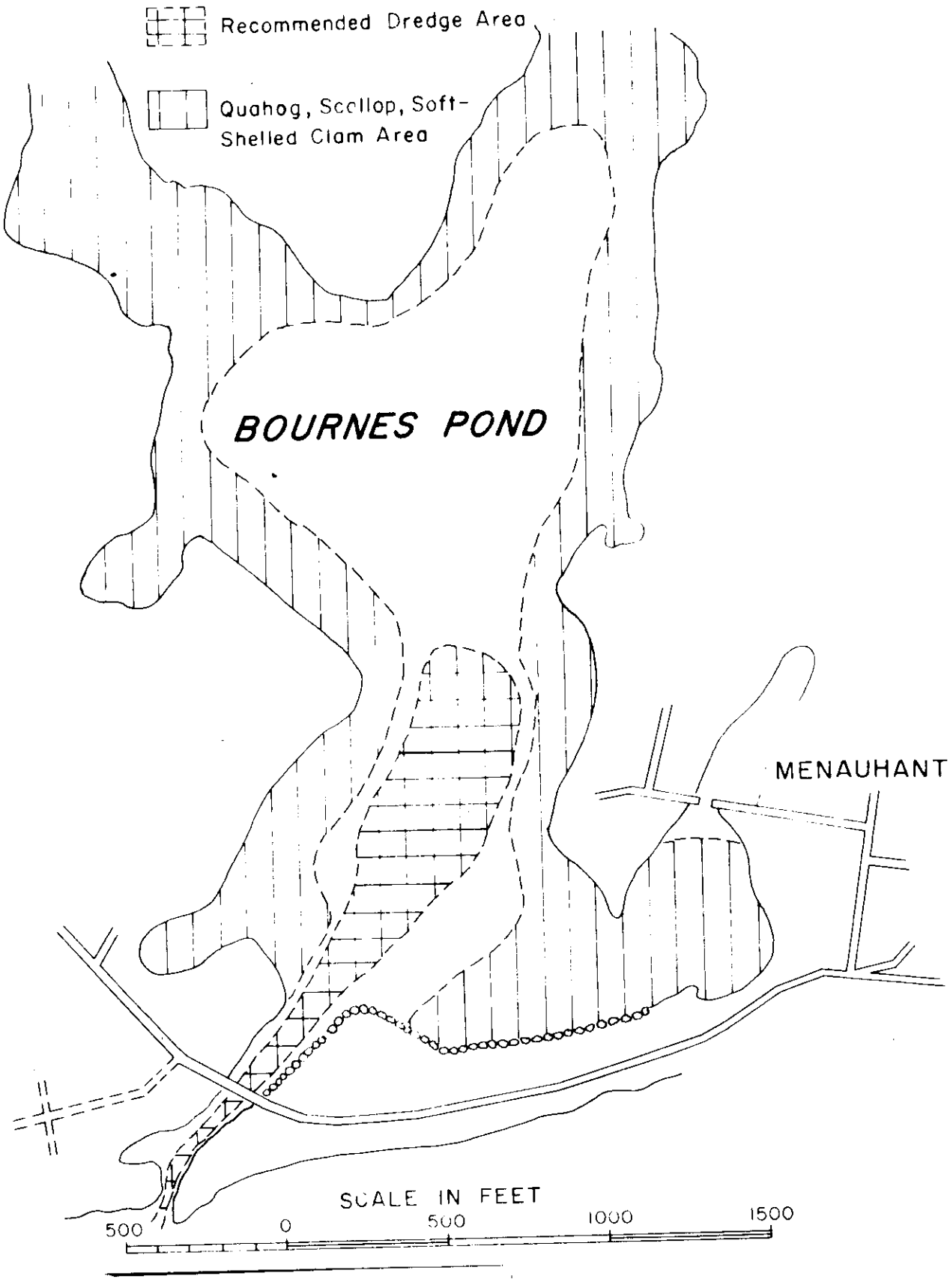


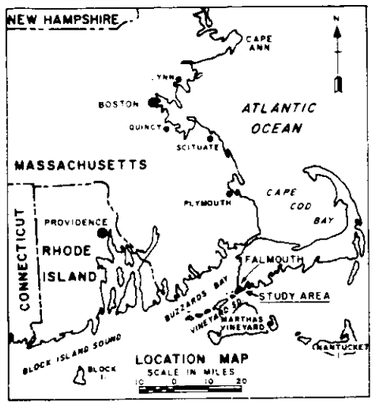
PLATE III

FALMOUTH BEACH EROSION



CORPS OF ENGINEERS

U. S. ARMY



COMPOSED OF DATA OBTAINED BY HINDCAST OF 3 YEARS OF WIND RECORDS (1948-1950) SHOWING PERCENT OF TIME WAVES OF DIFFERENT HEIGHT OCCUR FROM EACH DIRECTION FROM BEACH EROSION BOARD TECH. MEMO. NO. 55

WAVE ROSE

OFF NAUSET BEACH, CAPE COD, MASS.
(LAT. 41° 50' N, LONG. 69° 30' W)

*DURATION FOR EACH RANGE OF WIND SPEEDS IS MEASURED OUTWARD FROM TOP OF UNDERLYING BAR GRAPH

NOTE:
PERCENT DURATION PER DEGREE IS THE AVERAGE PERCENT DURATION OBSERVED FOR EACH 16 POINTS OF THE COMPASS DIVIDED BY 22 1/2 DEGREES.

WIND ROSE

MEMORIAL AIRPORT, NANTUCKET, MASS.
AUGUST 1952 - JULY 1957
AUGUST 1958 - JULY 1960
7 YEAR RECORD

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

BEACH EROSION CONTROL STUDY
OF FALMOUTH, MASS.
LOCATION MAP

SHEET OF — SCALE IN FEET 0 3000 6000 24000 — FEBRUARY 1962

APPROVED:

SUBMITTED:

TRANSMITTED WITH REPORT DATED DECEMBER 28, 1962

NO. B E MASS. 30

TRACED FROM U.S.C. & G.S. CHARTS 1209 & 1210

PLATE NO. 1

CORPS OF ENGINEERS

U. S. ARMY

N

LIST OF PROBINGS				
	ELEVATION BELOW M.L.W.			
	N. MASS.	DATE OF SURVEY	PENETRATION	MATERIAL
7	2.7	7-3-5	8	Sand to coarse sand to refusal
8	6.9	7-8-4	5	Sand to gravel to refusal

NOTES

Probings are in feet and tenths and are referred to the plane of Mean Low Water.

Probings taken with a 3/4" iron pipe forced down by 2 men in a skiff.

OYSTER POND

SALT POND

OWNER TOWN OF FALMOUTH

FALMOUTH BEACH

SURF

FALMOUTH HARBOR

OWNER TOWN OF FALMOUTH

WOODS HOLE

NEW HAVEN

NEW YORK

NOBSKA ROAD

NOBSKA POINT

OWNER UNITED STATES AND TOWN OF FALMOUTH

VINEYARD SOUND

LEGEND FOR SHORELINE STRUCTURES

Concrete

Wood

Steel

Stone & riprap

NOTES

Soundings are given in feet and tenths and are referred to the plane of Mean Low Water.

Shoreline is Mean High Water line; other shorelines are referred to Mean Low Water and are from U.S.C.&G.S. topographic maps Contour interval 0

Mean tidal range at Nobska Point 5.2

Hydrography, topography and shore structures from survey of May–Sept. 1962 by Corps of Engrs., supplemented by U.S.C.&G.S. Planimetric maps of 1948 and U.S.C.&G.S. aerial photographs of 1955.

Coordinates are based on the Lambert Grid System for the State of Massachusetts.

Soundings shown thus ● 8.1

Depth lines shown thus ---- 3 ----

1962 Shoreline shown thus ————

Shoreline from previous survey shown thus ————

Publicly owned shore shown thus ////////

Shore structures shown thus ———— ... ● Line referred to

Shore lines described in Appendix A

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

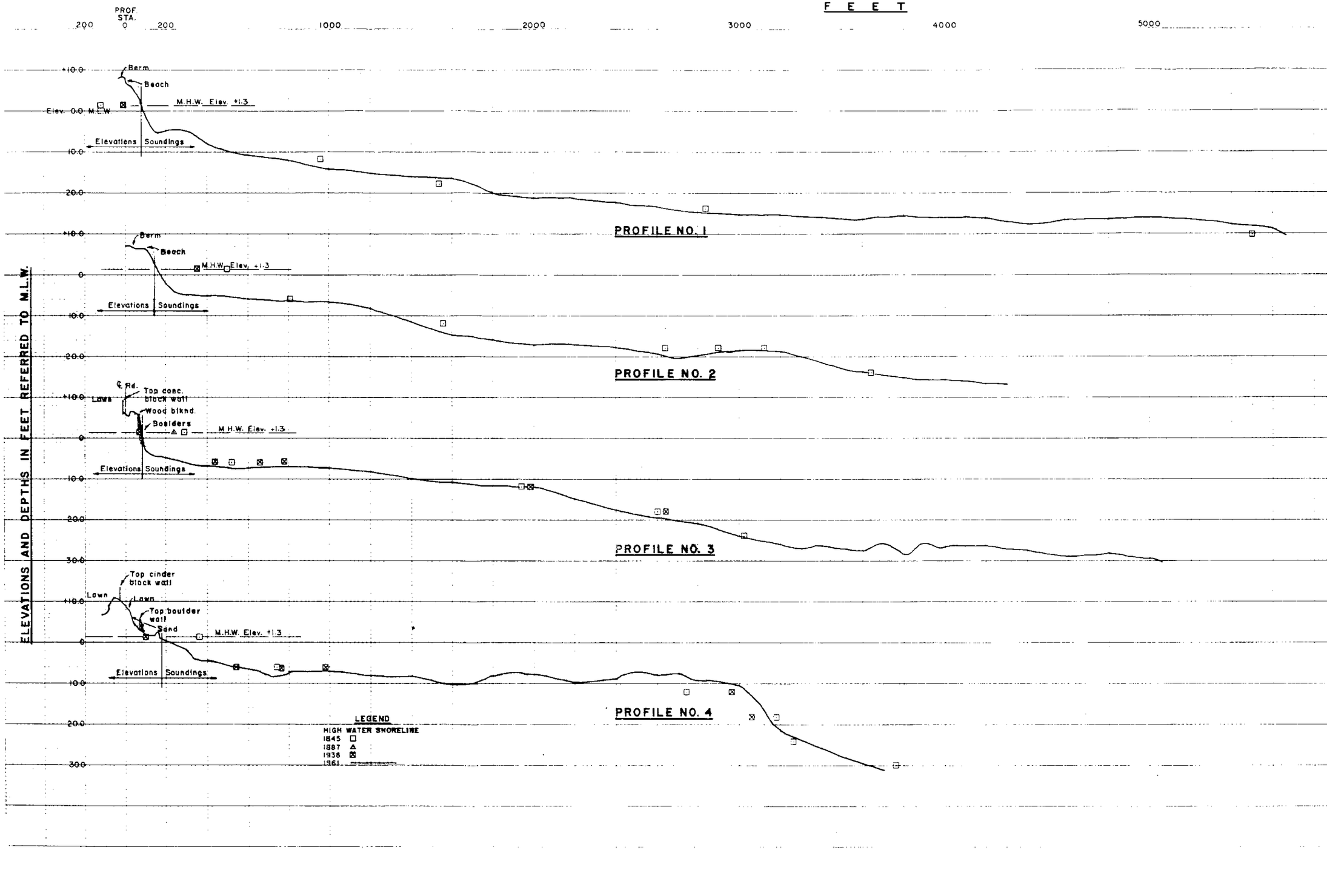
BEACH EROSION CONTROL STUDY
OF FALMOUTH, MASS.
SURVEY MAP

SHEET OF 3 SCALE 1 INCH = 400 FEET JANUARY 1962

TRANSMITTED WITH REPORT DATED DECEMBER 28, 1962

FILE NO BE MASS 3

PLATE NO. 2


FEET
PROF STA.
200
0
200
1000
2000
3000
4000
5000
ELEVATIONS AND DEPTHS IN FEET REFERRED TO M.L.W.
+10.0
0
10.0
20.0
30.0
Berm
Beach
M.H.W. Elev. +1.3
Elev. 0.0 M.L.W.
Elevations
Soundings
PROFILE NO. 1
PROFILE NO. 2
℄ Rd.
Lawn
Top conc. block wall
Wood bkhd.
Boulders
PROFILE NO. 3
Top cinder block wall
Top boulder wall
Sand
PROFILE NO. 4
LEGEND
HIGH WATER SHORELINE
1845
1887
1938
1961

FEET

PROF. STA. 0

200 200 1000 2000 3000 4000 5000

ELEVATIONS AND DEPTHS IN FEET REFERRED TO M.L.W.

10.0 20.0 30.0

PROFILE NO. 5

Lawn Berm Top boulder wall Beach M.H.W. Elev. +1.3 Elev. 0.0 M.L.W. Elevations Soundings

PROFILE NO. 6

+10.0 ℄ Rd. Top boulder wall M.H.W. Elev. +1.3 Elev. 0.0 M.L.W. Elevations Soundings

PROFILE NO. 7

+10.0 ℄ 22' Rd. Fill area Beach M.H.W. Elev. +1.3 Elev. 0.0 M.L.W. Elevations Soundings

PROFILE NO. 8

+10.0 ℄ 30' Rd. Top boulder wall Marsh Beach M.H.W. Elev. +1.3 Elev. 0.0 M.L.W. Elevations Soundings

PROFILE NO. 12

+10.0 ℄ 40' Rd. Grass Top conc. wall Beach M.H.W. Elev. +1.3 Elev. 0.0 M.L.W. Elevations Soundings

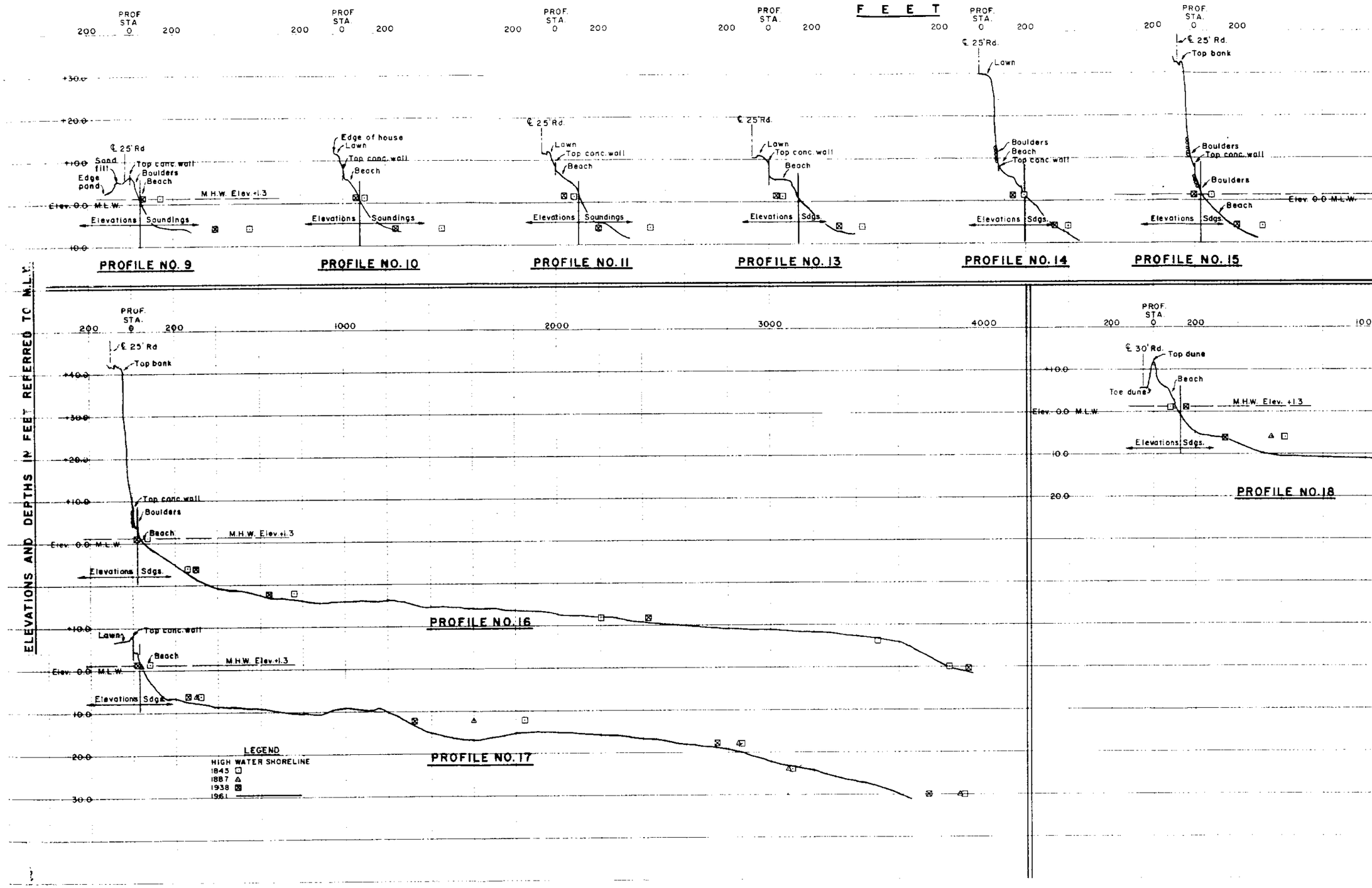
LEGEND

HIGH WATER SHORELINE

1845

1938

1961


FEET
ELEVATIONS AND DEPTHS IN FEET REFERRED TO M.L.W.
PROF STA 0
200
200
1000
2000
3000
4000
+30.0
+20.0
+10.0
10.0
20.0
30.0
℄ 25' Rd
Sand fill
Edge pond
Top conc. wall
Boulders
Beach
M.H.W. Elev. +1.3
Elev. 0.0 M.L.W.
Elevations Soundings
Edge of house
Lawn
Top conc. wall
Beach
℄ 25' Rd.
Lawn
Top conc. wall
Beach
Elevations Soundings
℄ 25' Rd.
Lawn
Top conc. wall
Beach
Elevations Sdgs.
℄ 25' Rd.
Lawn
Boulders
Beach
Top conc. wall
Elevations Sdgs.
℄ 25' Rd.
Top bank
Boulders
Top conc. wall
Beach
Elevations Sdgs.
PROFILE NO. 9
PROFILE NO. 10
PROFILE NO. 11
PROFILE NO. 13
PROFILE NO. 14
PROFILE NO. 15
℄ 25' Rd
Top bank
Top conc. wall
Boulders
Beach
Elevations Sdgs.
PROFILE NO. 16
Lawn
Top conc. wall
Beach
Elevations Sdgs.
PROFILE NO. 17
LEGEND
HIGH WATER SHORELINE
1845
1887
1938
1961
℄ 30' Rd.
Top dune
Toe dune
Beach
PROFILE NO. 18

ELEVATIONS AND DEPTHS IN FEET REFERRED TO M.L.W.

FEET

PROF. STA. 200 0 200 1000 2000 3000 4000

PROFILE NO. 19

℄ 30' Rd. Marsh Berm Beach M.H.W. Elev. +1.3 Elevations Soundings

PROFILE NO. 20

℄ 25' Rd. Sand fill Marsh Beach M.H.W. Elev. +1.3 Elevations Soundings

PROFILE NO. 21

℄ R.R. Edge of pond Beach M.H.W. Elev. +1.3 Elevations Soundings

PROFILE NO. 22

℄ Dirt rd. Lawn Lawn Berm Beach M.H.W. Elev. +1.3 Elevations Soundings

PROF. STA. 200 0 200

PROFILE NO. 23

Beach grass Berm Beach M.H.W. Elev. +1.3 Elevations Sdgs.

℄ 20' Rd. Grassy bank Riprap Riprap & boulders M.H.W. Elev. +1.3 Elevations Sdgs.

PROFILE

LEGEND

HIGH WATER SHORELINE...

1845 □

1887 △

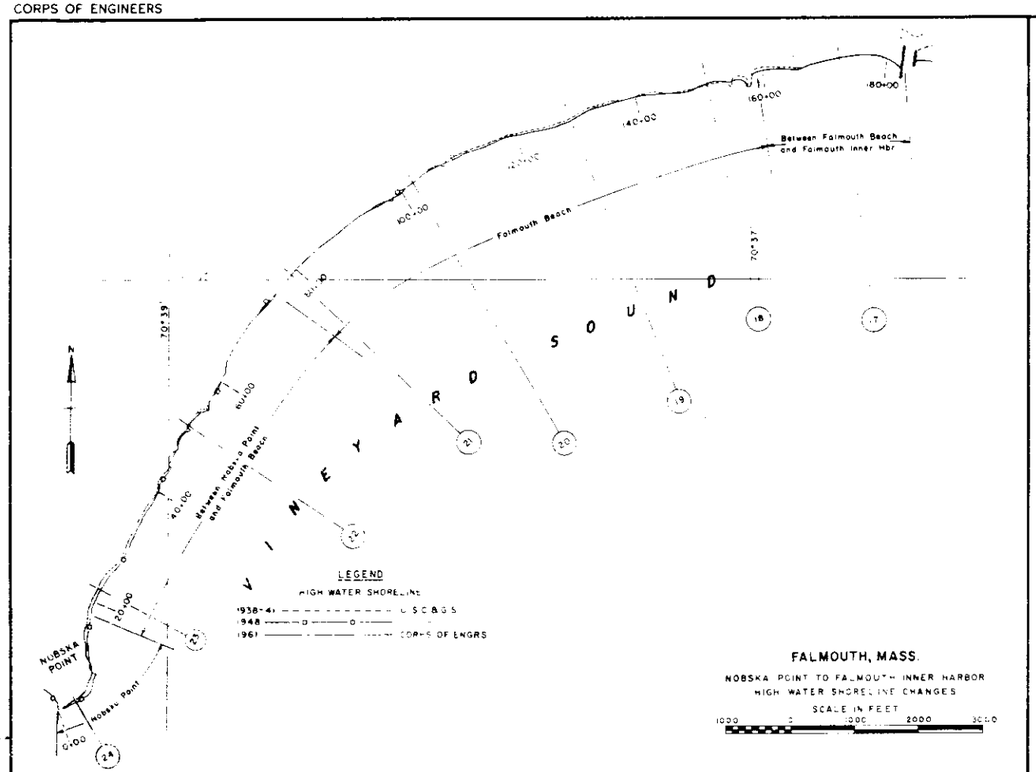
1938 ⊠

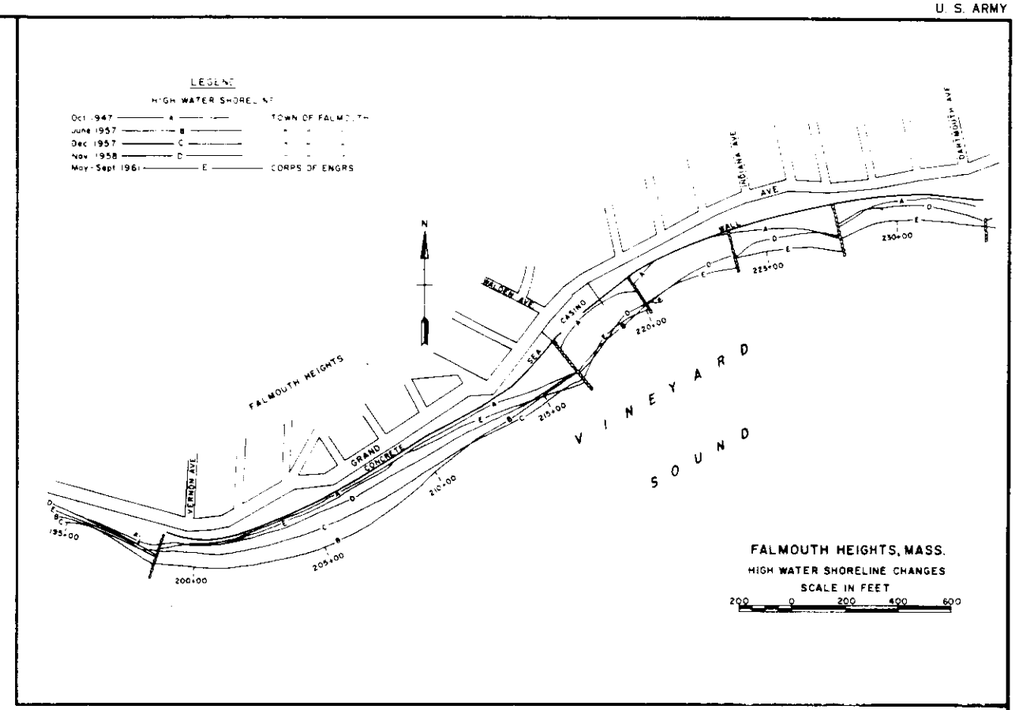
1954 ⊗

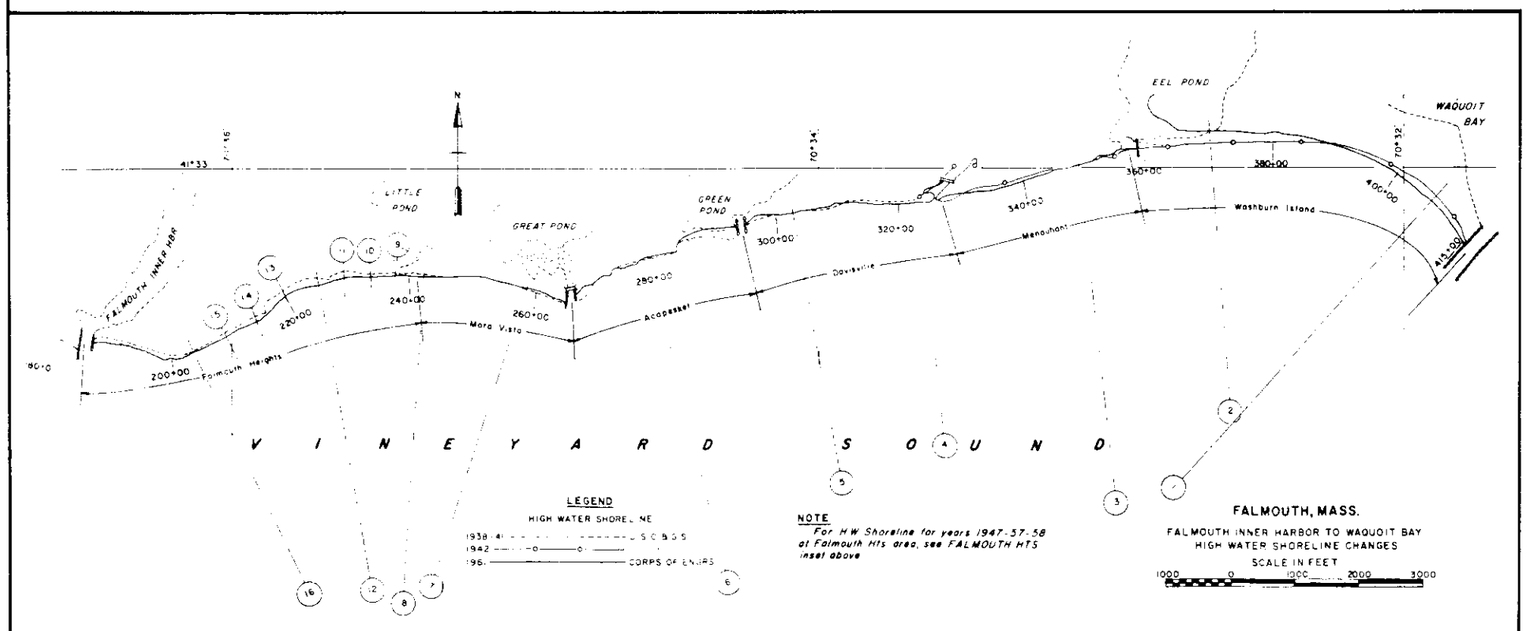
1961 ———

CORPS OF ENGINEERS

U. S. ARMY







U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

BEACH EROSION CONTROL STUDY
OF FALMOUTH, MASS.
HIGH WATER SHORELINE CHANGES

SHEET 1 OF 1 NOBSKA POINT TO WAQUOIT BAY FEBRUARY 1962
SCALES AS SHOWN

APPROVED: John W. Leslie
CHIEF ENGINEERING DIVISION

SUBMITTED: E. Pace
CHIEF, PLANNING AND REPORTS BRANCH

CHIEF, RIVER AND HARBOR SECTION — DR. BY: A.D.C.

TRP. A.D.C.

PROJECT ENGINEER — DR. BY: H.S.P.

TRANSMITTED WITH REPORT DATED: DECEMBER 28, 1962

FILE NO. B.E. MASS. 33

PLATE NO. 9

CORPS OF ENGINEERS

U. S. ARMY

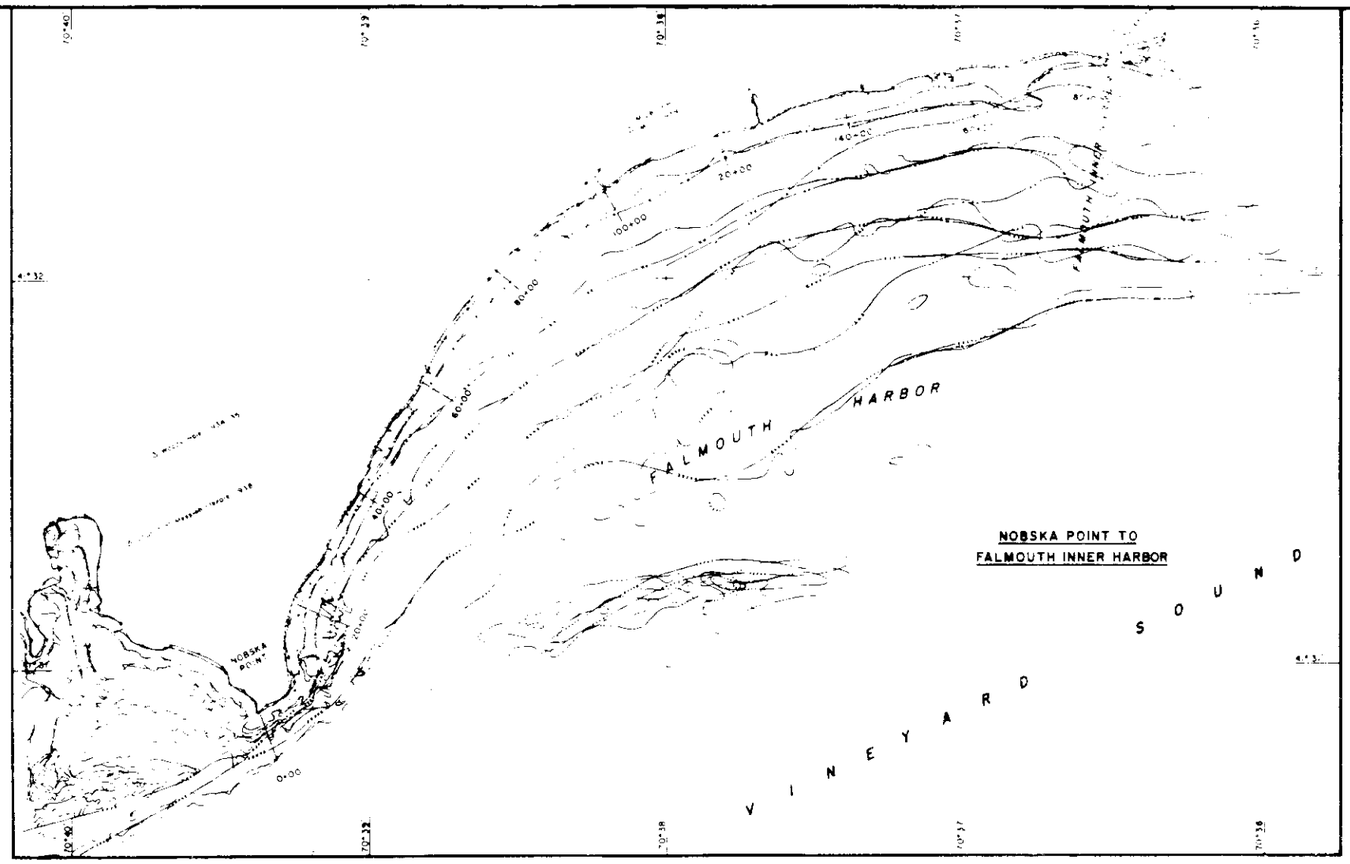
LEGEND

HIGH WATER SHORELINE

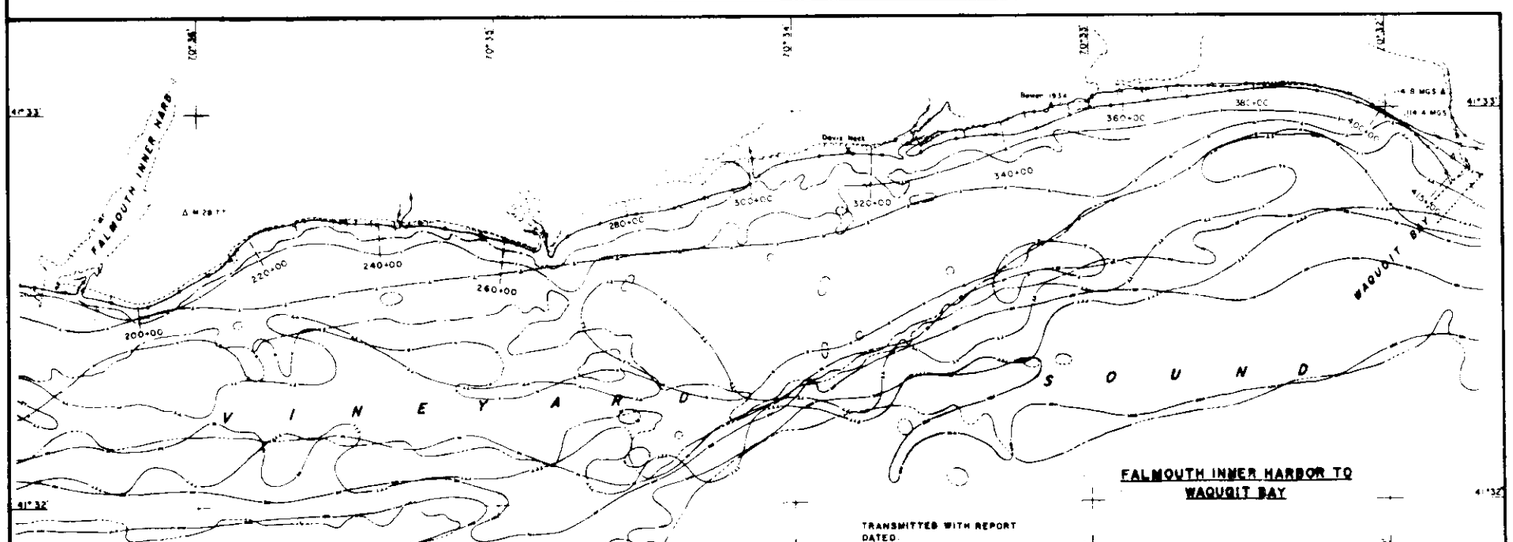
1845-46	U.S.C.&G.S.
1888-9	
1938-4	
1942	
1948	

DEPTH CURVES

	6 FT	12 FT	18 FT	24 FT	30 FT
1845					
1854					
1867					
1906					
1938					
1954					



NOBSKA POINT TO
FALMOUTH INNER HARBOR



FALMOUTH INNER HARBOR TO
WAQUOIT BAY

TRANSMITTED WITH REPORT
DATED

STATE OF MASSACHUSETTS

SHORELINE AND OFFSHORE DEPTH CHANGES

NOBSKA POINT TO WAQUOIT BAY

BEACH EROSION BOARD, WASHINGTON, D.C. JUNE 1961

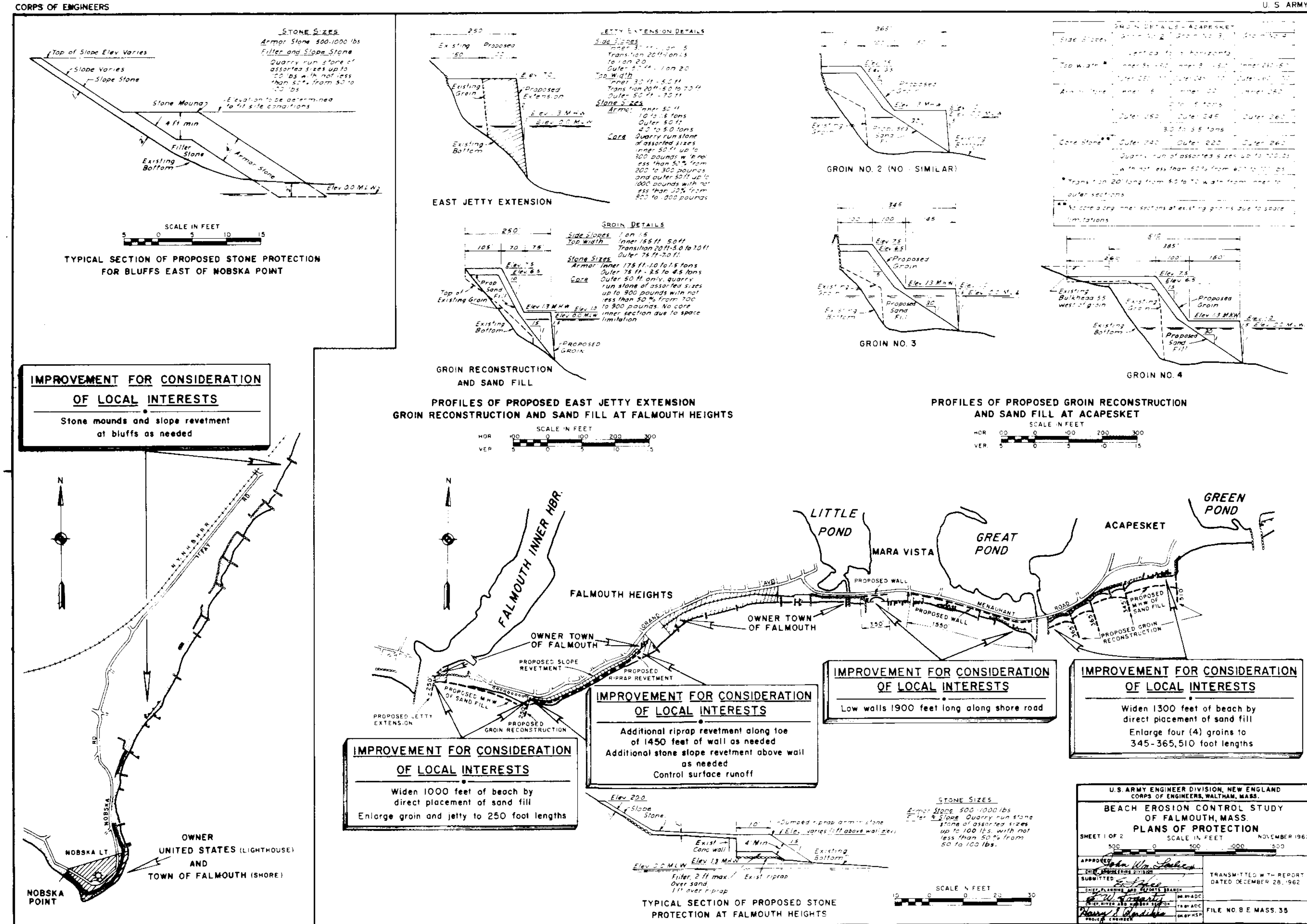
POLYCONIC PROJECTION DATUM NA 927

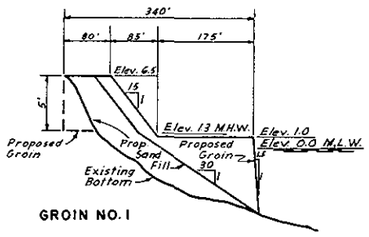
SCALE IN FEET

TRANSMITTED WITH REPORT
DATED DECEMBER 28 1962

FILE NO. B.E. MASS. 34

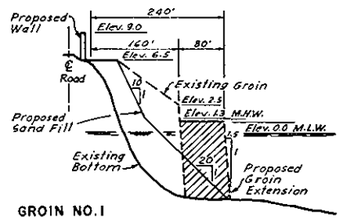
PLATE NO. 10


STONE SIZES
Armor Stone 500-1000 lbs
Filter and Slope Stone
Top of Slope Elev Varies
Slope Varies
Slope Stone
Stone Mound
Elevation to be determined to fit site conditions
4 ft min
Filter Stone
Existing Bottom
Armor Stone
Elev 0.0 M.L.W.
SCALE IN FEET
TYPICAL SECTION OF PROPOSED STONE PROTECTION FOR BLUFFS EAST OF NOBSKA POINT
IMPROVEMENT FOR CONSIDERATION OF LOCAL INTERESTS
Stone mounds and slope revetment at bluffs as needed
N
N.Y.N.H.&H.R.R.
RD.
NOBSKA
NOBSKA LT.
NOBSKA POINT
OWNER UNITED STATES (LIGHTHOUSE) AND TOWN OF FALMOUTH (SHORE)
Existing Proposed
Existing Groin
Proposed Extension
Existing Bottom
EAST JETTY EXTENSION
JETTY EXTENSION DETAILS
Side Slopes
Top Width
Stone Sizes
Armor
Core
Quarry run stone of assorted sizes
GROIN DETAILS
Side Slopes 1 on 1.5
Top Width Inner 155 ft 5.0 ft
Transition 20 ft-5.0 to 7.0 ft
Outer 75 ft-7.0 ft
Stone Sizes
Armor Inner 175 ft-1.0 to 1.5 tons
Outer 75 ft - 3.5 to 4.5 tons
Core Outer 50 ft only, quarry run stone of assorted sizes up to 900 pounds with not less than 50 % from 700 to 900 pounds. No core inner section due to space limitation
Prop Sand Fill
Top of Existing Groin
Existing Bottom
Elev 7.5
Elev 6.5
Elev 1.3 M.H.W.
Elev 0.0 M.L.W.
PROPOSED GROIN
GROIN RECONSTRUCTION AND SAND FILL
PROFILES OF PROPOSED EAST JETTY EXTENSION GROIN RECONSTRUCTION AND SAND FILL AT FALMOUTH HEIGHTS
SCALE IN FEET
HOR
VER
GROIN NO. 2 (NO. 1 SIMILAR)
GROIN NO. 3
GROIN NO. 4
GROIN DETAILS - ACAPESKET
Existing Bulkhead 55 west of groin
Proposed Groin
Proposed Sand Fill
Existing Groin
Existing Bottom
Elev 7.5
Elev 6.5
Elev 1.3 M.H.W.
PROFILES OF PROPOSED GROIN RECONSTRUCTION AND SAND FILL AT ACAPESKET
SCALE IN FEET
FALMOUTH INNER HBR.
FALMOUTH HEIGHTS
OWNER TOWN OF FALMOUTH
PROPOSED SLOPE REVETMENT
PROPOSED RIPRAP REVETMENT
PROPOSED MHW OF SAND FILL
PROPOSED JETTY EXTENSION
PROPOSED GROIN RECONSTRUCTION
LITTLE POND
MARA VISTA
GREAT POND
ACAPESKET
GREEN POND
PROPOSED WALL
MENAUHANT
ROAD
PROPOSED MHW OF SAND FILL
PROPOSED GROIN RECONSTRUCTION
IMPROVEMENT FOR CONSIDERATION OF LOCAL INTERESTS
Widen 1000 feet of beach by direct placement of sand fill
Enlarge groin and jetty to 250 foot lengths
IMPROVEMENT FOR CONSIDERATION OF LOCAL INTERESTS
Additional riprap revetment along toe of 1450 feet of wall as needed
Additional stone slope revetment above wall as needed
Control surface runoff
IMPROVEMENT FOR CONSIDERATION OF LOCAL INTERESTS
Low walls 1900 feet long along shore road
IMPROVEMENT FOR CONSIDERATION OF LOCAL INTERESTS
Widen 1300 feet of beach by direct placement of sand fill
Enlarge four (4) groins to 345-365,510 foot lengths
Elev 20.0
Slope Stone
Exist Conc wall
4' Min
Elev 1.3 MHW
Elev 0.0 MLW
Filter, 2 ft max. Over sand 1 ft over riprap
Exist riprap
Existing Bottom
TYPICAL SECTION OF PROPOSED STONE PROTECTION AT FALMOUTH HEIGHTS
STONE SIZES
Armor Stone 500-1000 lbs
Filter & Slope Quarry run stone stone of assorted sizes up to 100 lbs. with not less than 50 % from 50 to 100 lbs.
SCALE IN FEET
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.
BEACH EROSION CONTROL STUDY OF FALMOUTH, MASS.
PLANS OF PROTECTION
SHEET 1 OF 2
SCALE IN FEET
NOVEMBER 1962
APPROVED
CHIEF, ENGINEERING DIVISION
SUBMITTED
CHIEF, PLANNING AND REPORTS BRANCH
CHIEF, RIVER AND HARBOR SECTION
PROJECT ENGINEER
TRANSMITTED WITH REPORT DATED DECEMBER 28, 1962
FILE NO. B.E. MASS. 35



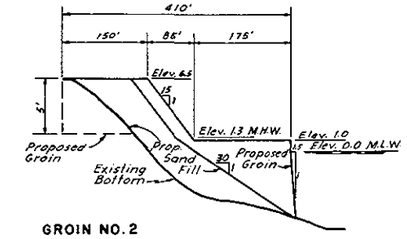
GROIN NO. 1

GROIN AND JETTY DETAILS - DAVISVILLE			
	Groin No. 1	Groin No. 2	Jetty
Side Slopes	1 vertical to 1.5 horizontal		
Top Width *	Inner 145'-5.0' Outer 175'-7.0'	Inner 195'-5.0' Outer 195'-7.0'	Inner 300'-5.0' Outer 210'-7.0'
Armor Stone	Inner 165' 1.0 to 1.5 tons	Inner 215'	Inner 320'
	Outer 175' 3.5 to 4.5 tons	Outer 195'	Outer 210'
Core Stone	Inner 165' Quarry run of assorted sizes with not less than 50% from 200 to 300 lbs.	Inner 215' up to 300 lbs.	Inner 320'
	Outer 175' Quarry run of assorted sizes up to 900 lbs. with not less than 50% from 700 to 900 lbs.	Outer 195'	Outer 210'
	* Transition 20' long from 5.0' to 7.0' width from inner to outer sections		

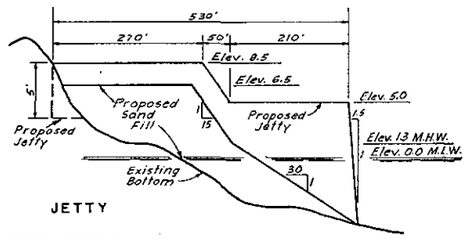


GROIN NO. 1

GROIN DETAILS - MENAUHANT			
	Groin No. 1	Groin No. 2	Groin No. 3
Side Slopes	1 vertical to 1.5 horizontal		
Top Width *	Outer 60'-7.0'	Inner 35'-5.0' Outer 225'-7.0'	Inner 40'-5.0' Outer 210'-7.0'
Armor Stone		Inner 55' 1.0 to 1.5 tons	Inner 60'
	Outer 80'	Outer 225' 3.5 to 4.5 tons	Outer 210'
Core Stone **	Outer 80' Quarry run of assorted sizes up to 900 lbs. with not less than 50% from 700 to 900 lbs.	Outer 150'	Outer 70'
	* Transitions 20' long from 5.0' to 7.0' width from inner to outer sections.		
	** No core along inner sections at existing groins due to space limitations.		



GROIN NO. 2

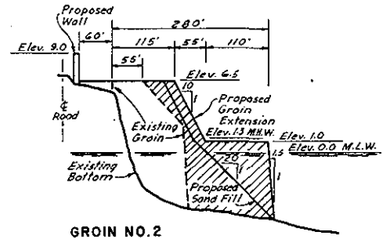


JETTY

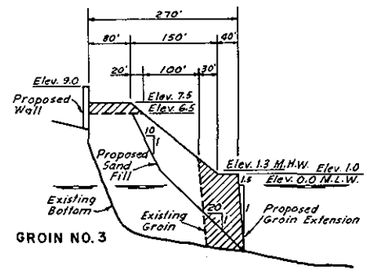
PROFILES OF PROPOSED GROINS
JETTY AND SAND FILL AT DAVISVILLE

SCALE IN FEET

HOR. 100 0 100 200 300
VER. 5 0 5 10 15



GROIN NO. 2

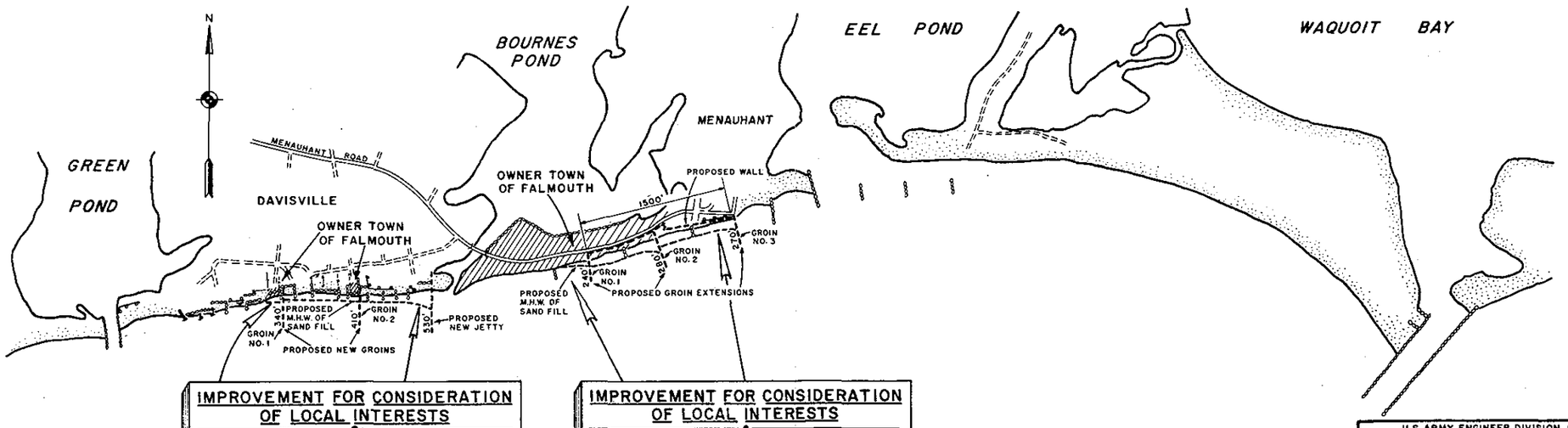


GROIN NO. 3

PROFILES OF PROPOSED GROIN RECONSTRUCTION
SAND FILL, AND WALL AT MENAUHANT

SCALE IN FEET

HOR. 100 0 100 200 300
VER. 5 0 5 10 15



IMPROVEMENT FOR CONSIDERATION OF LOCAL INTERESTS

Widen 1500 feet of beach by direct placement of sand fill
Two groins 340 and 410 feet long
Jetty 530 feet long

IMPROVEMENT FOR CONSIDERATION OF LOCAL INTERESTS

Widen 1600 feet of beach by direct placement of sand fill
Enlarge three groins to 240-280-270 foot lengths
Low wall 1500 feet long

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

BEACH EROSION CONTROL STUDY
OF FALMOUTH, MASS.
PLANS OF PROTECTION

SHEET 2 OF 2 SCALE IN FEET NOVEMBER 1962

500 0 500 1000 1500

APPROVED: Wm. Hall Jr. CHIEF, ENGINEERING DIVISION
SUBMITTED: CHIEF, PLANNING AND REPORTS BRANCH
CHIEF, RIVER AND HARBOR SECTION
PROJECT ENGINEER
DR. BY: ADC
TR. BY: ADC
CH. BY: HSP

TRANSMITTED WITH REPORT DATED: DECEMBER 28, 1962

FILE NO. B.E. MASS. 35

PLATE NO. 12

CORPS OF ENGINEERS

U. S. ARMY

LIST OF PROBINGS

NUMBER	DEPTH OF WATER	ELEVATION BELOW M.L.W. DEPTH OF PROBE	PENETRATION	MATERIAL
2	0.2	13.0	12.8	Mud to sand to sticky mud
4	4.4	14.6	10.2	Mud to sand to mud to hard sand to ref)
5	6.8	12.2	5.4	Mud and sand to sand to hard sand
6	14.1	17.8	3.7	Coarse sand to sand to hard sand

NOTES:

Probings are in feet and tenths and are referred to the plane of Mean Low Water.

Probings taken with a 3/4" iron pipe forced down by 2 men in a skiff.

70° 34'

E. 856,000

E. 858,000

E. 860,000

E. 862,000

E. 864,000

70° 32'

E. 866,000

N 204,000

N 202,000

N 200,000

N 198,000

41° 33'

DAVIS NECK

BOURNES POND

EEL POND

WASHBURN ISLAND

WAQUOIT BAY

MENAUHANT

DAVISVILLE

MENAUHANT ROAD

TOWN PARKING

SHEET 2

MATCH LINE

OWNER TOWN OF FALMOUTH

FALMOUTH MASHPEE

P-2

P-4

P-5

P-6

VINEYARD SOUND

LEGEND FOR SHORELINE STRUCTURES

Concrete

Wood

Steel

Stone & riprap

NOTES:

Soundings and elevations are in feet and tenths and are referred to the plane of Mean Low Water.

Shoreline is Mean High Water. Land contours are referred to Mean Sea Level, and are from A.M.S. topographic maps Contour interval 10'. Mean tidal range at Waquoit Bay is 1.1'

Hydrography, topography and shore structures from survey of May--Sept. 1961 by Corps of Engrs., supplemented by U.S.C.&G.S. Planimetric Maps of 1938-1941 and C.&G. aerial photographs of 1955.

Plane coordinates are based on the Lambert Grid System for the State of Massachusetts.

Probings shown thus ●P-10

Profiles shown thus ——(12)

1961 Shoreline shown thus ——

Shoreline from previous surveys shown thus ——

Publicly owned shore shown thus ////////

Shore structures shown thus [13]—— are referred to description detailed in Appendix G.

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

BEACH EROSION CONTROL STUDY OF FALMOUTH, MASS.

SURVEY MAP

SHEET 3 OF 3

SCALE IN FEET 500 0 500 1000 1500

JANUARY 1962

APPROVED: John W. Leslie

CHIEF, ENGINEERING DIVISION

SUBMITTED: E. Lobe

CHIEF, PLANNING BRANCH

CHIEF, OPERATIONS BRANCH

NEW YORK AND BOSTON DIST.

DIV. ENGR.

PROJECT ENGINEER

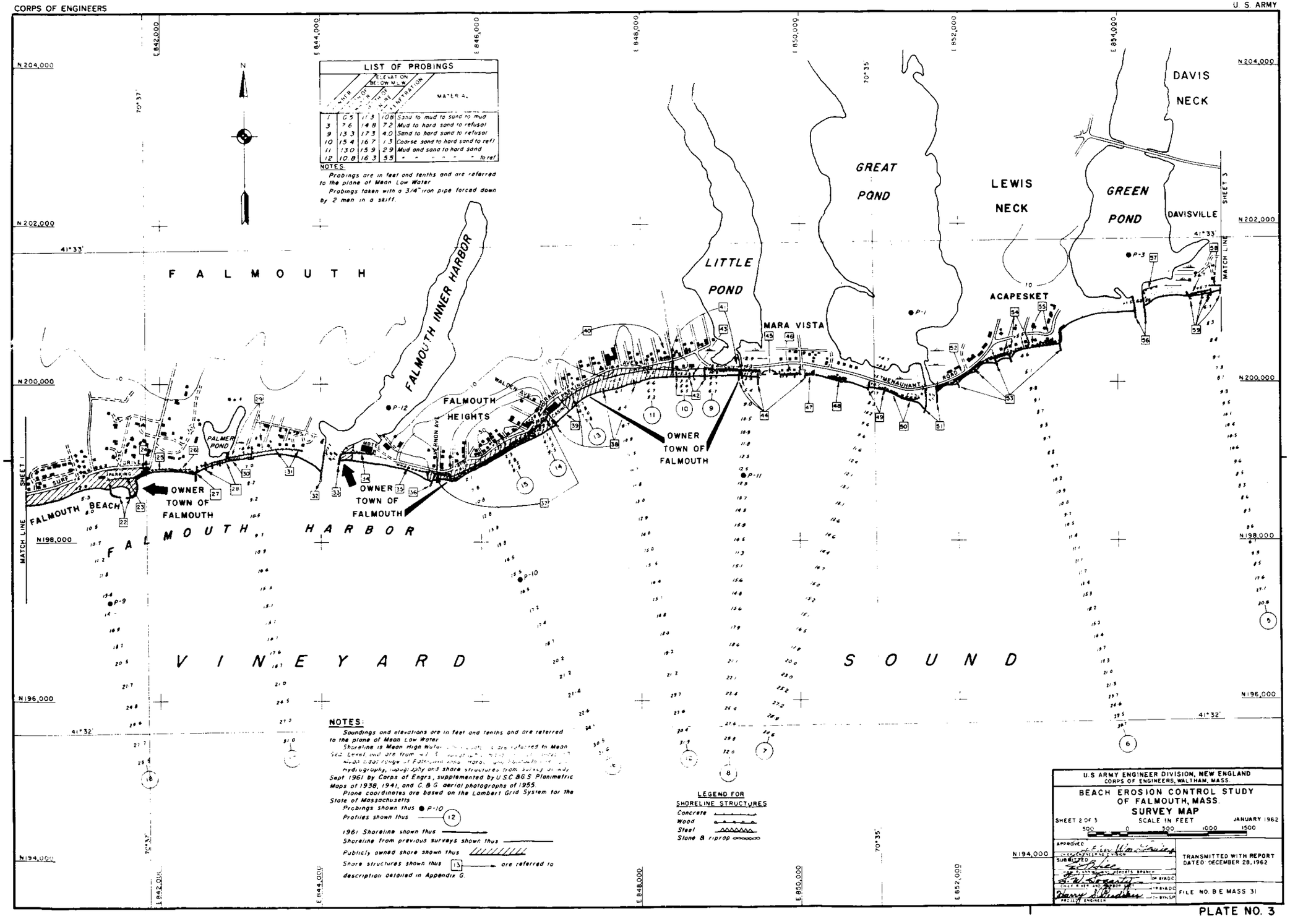
TRANSMITTED WITH REPORT DATED: DECEMBER 28, 1962

FILE NO B.E. MASS. 31

PLATE NO. 4

CORPS OF ENGINEERS

U. S. ARMY



U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

BEACH EROSION CONTROL STUDY OF FALMOUTH, MASS.

SURVEY MAP

SHEET 2 OF 3 — SCALE IN FEET (500 0 500 1000 1500) — JANUARY 1962

APPROVED: [illegible] CHIEF ENGINEERS DIVISION

SUBMITTED: [illegible] CHIEF, ENGINEERING REPORTS BRANCH; [illegible] CHIEF, PLANNING DIVISION, NEDBYADC; [illegible] CHIEF, FIELD WORK AND SURVEY BRANCH, NEDBYADC; [illegible] PROJECT ENGINEER, NEDBYSP

TRANSMITTED WITH REPORT DATED DECEMBER 28, 1962

FILE NO. B E MASS 31

PLATE NO. 3